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BLIND GIRL AT TAPESTRY LOOM

SEARCHLIGHTS ON SOME AMERICAN INDUSTRIES

BY

JAMES COOKE MILLS

AUTHOR OF "OUR INLAND SEAS"

WITH ILLUSTRATIONS FROM PHOTOGRAPHS AND DRAWINGS

CHICAGO

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1911

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COSHOCTON, U. S. A.

TO

THE CAPTAINS OF INDUSTRY WHOSE
BRAINS AND CAPITAL HAVE MADE
THE EVOLUTION OF THESE
GREAT INDUSTRIES A
STORY WELL WORTH
TELLING

227160

PREFACE

IT is an inexplicable assumption, though an ancient one, that history, as written, should consist of little more than the records of the overthrow of kingdoms and empires, tales of intrigues and political strife, and accounts of wars, sieges, and slaughters. This idea of history deals with the barbaric, and takes no account of a nation's intellectual and religious development, its arts and letters, or its industrial progress and commercial expansion. It magnifies the brutal and passionate nature of man, and belittles the æsthetic side and that resolute spirit of thrift and industry that makes nations respected.

In this enlightened age the life and evolution of the American people lie in their quiet, peaceful, and productive efforts, and in the thoughtful conduct of their affairs. The nation is great through its architects, engineers, inventors, artists, economists, teachers, business men, and great army of workers, and not through its military and naval forces, its political octopuses, or its lawyers, preachers, and policemen. The proud place Columbia holds among national figures of the world is due to commerce and labor, production and distribution. As a noted writer has said: "Individuals at work are safe; and a nation is only safe when the greatest proportion of its people are employed in useful effort."

Taking, then, this thought as a maxim, I have steadily endeavored to collate facts and analyze the results produced by certain of our leading American industries, and to present clearly and concisely the mechanical and economic aspects of their operation. Scientists, engineers, mechanics, and tradesmen have their technical books,

dry-as-dust monographs, and scientific and trade papers, all couched in language and terms so technical and confusing as to be almost unintelligible to laymen. This book, on the other hand, is intended primarily for the layman — the scholar, the student, and the general reader; and the author has aimed at an interesting style calculated to hold the attention and aid the memory.

The scope of the work necessitated great research, careful selection of important facts and figures, and the avoidance of technical language. The subjects chosen for this volume are all of vital importance to the prosperity of the country, but the requisite data are widely scattered, and in some instances difficult of access. Each chapter contains all the information essential to a thorough understanding of the industry with which it deals. All the facts stated have been carefully examined to determine their authenticity, and have been arranged in logical order. In many respects the story is an amazing account of human achievement in the mechanical arts, but everything told is fully substantiated. In this progressive age the American workman, of whatever profession or trade, should be regarded as the greatest figure in history.

J. C. M.

SAGINAW, MICH.,
July 1, 1911.

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SEARCHLIGHTS ON SOME AMERICAN INDUSTRIES

I

LUMBER

THE CONQUEST OF THE FOREST

THE FOREST TO BE CONQUERED — THE PIONEERS AND SKIRMISHERS — THE CAMP AND THE ARMY — THE LOGGING, RAFTING, BOOMING, AND SAWING OF THE PINE — LABOR-SAVING MACHINERY — FROM LOG TO LUMBER — FROM LUMBER TO MATCHWOOD — EARLY METHODS OF OBTAINING FLAME — DETAILS OF MATCH-MAKING — HABITAT OF THE LODGE-POLE PINE — ITS USES — THE AMAZING EUCALYPTUS — ITS USEFULNESS FOR MANY PURPOSES — LUMBER PRODUCTION IN THE UNITED STATES.

FAR up in the north country away from the world of the familiar, which has grown wearisome, the traveller comes at length to the deep forest, which is indeed a world of the something new. In seeking out the battle-ground of the lumber-jack to see how the forest giants are laid low by ceaseless conquest, he travels over a rough and bleak country. For the better part of a day the railway train, drawing farther from industrial communities, skirts the edge of the northern wilds. Sometimes it twists around perilous side hills and across burned slashings thick with blackened stumps, while now and then it darts through stretches of virgin wood. From scenes of desolation it finally comes out in a clearing and stops at a little station, from which there opens to the traveller's view a wide vista of dark wooded shores and the icy coating of a crescent-shaped bay. Here, at the mouth of a rapid river, he is on the border between semi-

civilization and the almost unbroken and unknown forest wilderness. The balsamic and pitchy smell of the pine, which is one of the charms of the north woods, is wafted in by wintry winds, and lures him on into the depths of the evergreen and sometime snow-mantled forest. It is here that the solemn stillness of the primitive domain is sublime; and is broken only by the faint and distant sounds of the conflict between Man and the forces of Nature for the recovery and control of the earth's treasure-house.

Diving into the deep pinery as into a canyon of verdure, a little logging train of empty flats and a cabin car rolls along the rough and crooked road, carrying him into the very wilds. Rushing past Ten Mile Spur and Hoop Spur at a rattling pace, and out on Walsh's Siding, it seems, by the continual swaying and bumping of the cars, that the curious, hump-backed engine is doing its level best to reach the end of the line in record time. Thus the traveller comes to the opening among lofty pines, where Logging Camp No. 6 squats low in the thick, moist undergrowth, the landings piled high with new logs; and then, on to a still steeper skidway worn bright by the downward rush of ponderous, shaggy logs. Here the axe-man, the sawyer, the swamper, the barker, the dog-chain tender, the donkey-engine men, and the road-monkeys are at work on the destruction of the forest.

But before the army of invasion that is conquering the pinery makes its first advance into the wood in early winter, the "cruisers," or land-lookers, tramp through the wilds, and other woodsmen — the skirmishers — follow and blaze the way. The cruiser is often called upon to begin the conquest in the dead of winter, when the snow lies from three to five feet deep in the woods; but he is undaunted by the worst of winter conditions. It is his business, and it pays well. He is warmly outfitted with the heaviest woollen blankets and clothing; and with extra coverings and the few articles of camp equipage packed

on his back, he trudges on snowshoes for miles through the native forest. He carefully examines section after section, and computes to a nicety the number of millions of feet of standing timber, sometimes covering as much land as would be contained in several counties in the States, and finally reaches a correct estimate of the grades suitable for match and other lumber. In this work he is drawn into the very depths of the forest far from the iron trail and the habitations of man. He will sometimes be lost to the outside world for weeks at a time penetrating into the thickest pineries, and without seeing the face or footprint of man for days. The deer, elks, bears, timber wolves, and other wild animals of the native forest are his curious and not always harmless visitors. When he returns to civilization and makes his report to the lumber barons, the large tract may be bought outright, the deal requiring millions of dollars.

Late in the summer the skirmishers break through the forest and locate the camp where the ground is high enough to be quite dry. Then they proceed to make a clearing, using the logs from the felled trees to build the cabins which are the home of the army of lumber-jacks during the long winter. In all there are six log shacks, no two of which are alike in shape or size. While this work is going on, gangs of road-makers are cutting a wide trail through the forest, to connect the camp with the branch railway four or five miles away. This road is usually completed and in operation before the first fall of snow, thus opening communication with the base of supplies. The men then open up a tote-road straight out into the woods, and start branch lines from it to right and left. Along these roads at convenient points skidways are built of long slender logs laid side by side on the cleared ground, about five feet apart, and are held in place by stakes and braces. On these skids the logs, as they are cut, are stacked until hauled to the banking ground. These preliminary operations done and supplies

in store, the camp is ready for the lumber-jacks' winter attack on the forest monarchs. The red-sash men of the woods take up the campaign, reaping where they have not sown: they draw riches from the combined elements of earth, sky, and air, rendering the product of the forest of use to mankind.

Travellers usually reach the camp at dusk; and he must be indifferent to surroundings who is not ready and eager to study the lumber-jacks in camp as well as in action, forgetting personal comfort the while. Of the group of cabins covered with a thick mantle of snow, the men's camp is the first to attract attention. It is one large room with bunks arranged along the walls two or three tiers high and filled with balsam boughs and hay or straw, over which are spread coarse but warm blankets. The pillows are sacks stuffed with hay. Near each end of the room is a big box stove; and in one corner is a rough wooden sink set out with tin basins and flanked by roller towels and a barrel of water, whereat the woodsmen make their toilet. Placed about the room are rude tables and benches where the men pass the short evenings and Sundays at cards, or smoke the time away. In the gathering are Swedes, Belgians, Italians, Indians, and half-breeds, besides a liberal sprinkling of young Canadians. They keep the camp stirred up and in uproar by telling of life and thrilling experiences in many climes. The strenuous and dangerous incidents of a rough life are of the utmost human interest to these hardy men.

Of only slightly less interest, and perhaps of more concern to the lumber-jacks, is the cook camp, which also is one large room with a huge range and cook-table in one end. Here the fat cook and his "cookee," clad in their oil-cloth aprons, are bringing on huge pans of beans, sow-belly, potatoes, and soda-bread; then they bring coffee and prunes to top off with; for the evening meal is ready. The long tables, on which the tempting spread

CORNER OF "CHUCK SHANTY"—TABLES SET FOR EVENING MEAL

FAMISHED LUMBER JACKS' NOON MEAL AMONG PINES—"COOKIE'S" SLED AND HORN IN FOREGROUND

is laid, are set with a great array of tin plates, tin dishes, and tin cups or rather basins; the knives and forks are of steel, with heavy iron handles. Along the walls back of the tables are lines of posters in bright colors, of *advertisement girls;* below the posters are canned vegetables and packages of tobacco. Even as the cook lays out the last dish of steaming-hot "truck," the hungry men troop in with loud shouts and much stamping of feet, and rush for bench seats at the tables. It is amusing to watch these ravenous men at their meal; and eating seems to be to them a matter of work rather than of pleasure. There are no waiters to hand out the dishes; therefore every man reaches out and helps himself. Sugar and milk are dealt out in coffee cans, while the salt and pepper shakes are merely baking-powder cans with nail-hole perforated tops. But the lumber-jack is not a fastidious person, and he enjoys his "feed"; there is abundance of everything, and the average appetite is seldom sated with less than about three plates of each item on the list, and as many cups of black coffee.

The stables are much like the other shanties, but have lower roofs that the animal heat of the horses and oxen may go as far as possible toward keeping them warm. The blacksmith shop is also low roofed; and the storehouse, located alongside the cook camp, is still lower and almost buried in snow to keep out frost, so that the quantities of provisions within will not be damaged. The office, or "van," as it is called in the parlance of the camp, is a little log hut standing by itself wherein the camp-clerk keeps the books of account and lists of the general merchandise needed by the men. There is a full stock of Mackinaw jackets, stag-pants, heavy woollen underwear, socks, hurons, shoepacks, mittens, and caps; also tobacco, pipes, and a little stationery. Here are also the bunks of the camp foreman, the scaler, and the clerk, and several extra ones for the big bosses and visitors. The traveller is assigned one of these and made to feel

at home by foreman "Bill" and by "Chris," the van-keeper. At eight o'clock, when all lights in camp go out, he too tumbles into his bunk after a busy but profitable day, the experiences of which were but forerunners of stranger sights and scenes.

Long before daybreak the camp is astir. The coming of the chore-boy is the first call to arms. He lights a fire in the big box stove, and soon every nook and corner of the little shanty is aglow with warmth. By the dim light of a lantern all turn out and, after a hasty toilet, hurry to the cook camp. The traveller is with the crowd, as nothing of the day's routine in the deep woods must be missed.

As the first rays of the rising sun pierce the tops of the forest giants, and the deeper shadows in the woods fade away, the lumber-jacks come forth for the day's onslaught. What a motley and picturesque group they make, as they press on over the main logging road, out into the forest. The Mackinaw jacket — a veritable gorgeous sunset of red — together with yellow-and-green plaid stag-pants, is much in evidence, while the assortment of flannel shirts, Scotch caps, German socks, and hurons, could not be matched anywhere. Along the glary surface of the ice road, made so by fresh sprinkling the late afternoon before, the decking teams and drays plod their way, taking the army of workers to the combat. Every now and then gangs of them drop off the sleighs or the drays, and delve into the thick undergrowth, to this side and that. A mile and a half, two miles, and even three they go, into the very depths of the primeval forest, where the clean bright snow is a fit covering for the moss and ferns two or three feet beneath, and untouched by the shoepacks of the woodsmen. This indeed is the heart of the north woods. The swish of the wind through the broad branches is pleasant to the ear; while occasionally from afar out in the forest come the rattling, tinny sounds of

the donkey-engine as it winds its cables, and less frequently the whistled signal of some invisible log-boss.

First comes Pete, the head feller, who picks the tree to be laid low, and, looking up its mighty bole a hundred feet or more, decides the direction of its fall. Then, selecting the place where it shall lie so that its falling will do the least injury to the standing pines, he cuts out a notch in the bark of each of several trees to indicate the lane, and passes on. Following him come the real fellers — the axe-men and the sawyers — who fell the doomed tree. The axe-men fall to their work with a vim, for the air is nimble with cold, and soon the kerf or notch on the side toward which the tree is to fall is a foot or more deep in the clean white wood. Skilfully has this notch been made, for it is this that governs the fall of the tree; and all the ground beneath is covered with pitchy chips, as the choppers cease. Of all the forest workers these are the men whose judgment never fails; where the pine should fall, there it falls. Set a stake fifty feet from the foot of the pine, and they so cut the kerf that the falling tree will drive it into the ground.

Now, as the choppers follow the trail of Pete, there is much hard work for the sawyers ere the noble tree gives up the strife. They begin with their long double-toothed saw, one at each end, on the side of the trunk opposite to the notch. Steadily these sawyers draw the swift-cutting saw back and forth, back and forth, through ring upon ring of the tree's yearly growth, and on into its very heart. Frequently they stop to oil the gummy blade with kerosene to remove the pitch, and drive wedges into the kerf to ease the saw slightly, and also to help the notch to guide the tree in its fall. Still the sturdy pine, standing as firm and solid as a rock, gives no sign of yielding. Only when the tearing saw has cut through its heart and beyond, are heard the sharp cries of distress, a sound of rending wood, of cracking fibres, penetrating and far-reaching. "Watch

out there!" roars Pete. "Out of the way! Watch out! Watch out!"

Even as he yells the wedges are sledged home, the mighty tree is forced over, it loses its balance. The cries of distress increase, they grow louder, the fibres break off with quick cracks, the top sways aside slowly at first with matchless dignity even to the last. The branches moan as they sweep through the air, and, as they gather speed, the moan becomes a whistle and then a shriek. Faster and faster falls the tree until it strikes the ground with a tremendous crash, jarring the forest, the sound reverberating through the dense woods, hoarse, appalling, the death cry of the pine.

Before the conquerors lies the prostrate tree that in the days of the Pilgrim Fathers was a promising sapling. Through two centuries and more it grew and waxed strong, defying the fiercest storms and shocks of the elements of air and sky. It seems almost a tragedy that it should be laid low; but such is the conquest of the forest.

Now it is time for luncheon, and the other Petes and their crews come romping through the deep wood on every side, from far and near, at the call of the horn. The cookee with the truck-sled has come the long way from camp; and he is welcomed with a mighty shout from the famished lumber-jacks. For each one there is a pyramid of cold beans, three boiled eggs, five or six wedges of bread, cold ham in quantities, three cups of coffee, and crackers — a meal in proportion to the work.

Back to their tasks in the deep woods go the lumber-jacks, while the traveller falls back to the felled tree where sawyers, after measuring the trunk, are sawing it up into logs, twelve, fourteen, and sixteen feet in length, and clearing off the branches. Then from out of the woods come "swampers" who cut paths through the brush to the dray road. These men are the recruits — the least experienced men in camp; and the paths are no more than trails. And now the heavy teams or yoke of

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CHOPPERS AT WORK IN FOREST

RECORD LOAD HAULED BY ONE TWO-HORSE TEAM

SNAKING LOGS OUT TO SKIDWAYS

oxen come up the trail drawing drays, and followed by a driver and dog-chain tender. Quickly they roll one end of a log on the crossbeam of the low dray, cast a chain over and around the log, and secure it. A strong pull by the teams brings the log out straight behind, the other end dragging along over the snow. To watch this particular log and see where it goes, the traveller follows the skidding crew, and presently comes out rather unexpectedly on a branch of the main log-road. Here is a skidway piled high with logs, snaked out and stacked, ready for the long haul in mammoth loads, to the banking ground beyond the camp.

While he wonders how the great rough logs are loaded on the strong and heavy sleighs, tier upon tier, until finally the " peeker " is in place, a snaking-crew comes upon the scene from toward the camp, and, in the regular course of loading, makes the operation clear. The team is first unhooked, a long but light chain is secured to a stake opposite the skidway and then passed over the sleigh and around the first log, while the other end is fastened to the team's crosstree. When the team moves out into the woods at right angles to the skidway, the log rolls over and over guided by cant-hook men, until it is rolled in place on the sleigh. As the pile grows there is great danger to the top-loader, the man who receives the log on the sleigh, and many an arm or leg is lost or worse happens, in placing the " peeker."

In some places in the forest where the felling is on hillsides or in marshy spots, donkey-engines are used in skidding and snaking through the woods. These cumbersome machines move about on skids or runners with a long heavy chain, one end of which is fastened to a tree some distance up the road, and the other end is wound around the drum of the engine. The operation of skidding is the same as with horses or oxen.

As we return to camp on a mammoth sleigh-load of logs, we may often pass a crew of " road-monkeys " work-

ing on the ice roads, to keep them solid and firm and with a glary surface. This work is of much importance, for upon the condition of the roads depends the size of the loads that can be hauled; and the expense of logging depends more or less on that. The work is simple, and is easily done by means of a wooden tank mounted on runners, with small holes in the back end at the bottom. Where the road is rough and the ice soft, a scraper is hauled along ahead to level off the surface and remove sticks and rubbish. The tank follows sprinkling the surface evenly, and during the night it freezes hard. The next day mammoth loads can be hauled with one team. One season the record load was 23,576 feet, log scale.

Down below the camp a little way, and along the railway track, is a banking ground, where the logs are stacked so that the loaders may roll them on the flat cars, and that the train crews may haul them away to the sawmill of the company, on the shores of the little bay. Several miles to the west, on the banks of a little stream, is another banking ground, where the logs cut near-by are dumped. When the ice and snows of winter have melted away, the logs float down to the main river. There the "boomers"—the river men—guide them into booms where they are rafted and towed to the storage boom of the match-timber sawmill.

The snow locomotive is a unique form of traction engine; it effects economics in hauling logs, poles, ties, and other products of the forest from remote camps or outposts to the nearest railway spur or stream. It is intended for use only on ice or snow, but its one hundred horsepower is sufficient to haul from seven to ten heavily loaded logging-sleds at a speed of four or five miles an hour over almost any kind of frozen road. The front end is supported by a pair of bob-sleds which turn on a pivot, so that the locomotive can be steered, a worm-gear with rod and wheel being provided for that purpose. The steerer sits on the pilot almost under the little headlight, and di-

rects the course of the train, very much like the driver of an automobile.

There are four cylinders working vertically, two on each side of the boiler, and the crank shaft of each engine is connected by spur pinions to driving shafts running lengthwise beneath the boiler. On the rear end of these shafts are attached bevel gears which mesh in large gears running on quills; and the power is transmitted by intermediate gears to the rear sprocket. The two driving-wheels on each side of the engine do not bear directly on the snow or ice, but are mounted on heavy endless chains, twelve inches wide and twenty-eight feet long, and the power is conveyed to them by strong sprockets. As these sprocket drivers revolve by the transmitted power of the engines, the endless chains are moved forward and the locomotive with them. The rear pair of sprocket drivers is connected to the forward or power-driven drivers by inner endless chains running over smaller sprockets.

In summer, logging-operations in the forest go on more or less actively, but the methods employed are somewhat different, because of the lack of snow and frost, and the consequent softness and unevenness of the roads through the woods. The snaking and skidding operations are done by steam donkey-engines and the loading on cars by steam log-loaders of the McGiffert type. Where the logs are lying within a thousand feet of the railway tracks, the huge double-armed octopus stretches out its tentacles — steel cables — and grips one end of a log with stout tongs, very much like an iceman's tongs. Winding on the revolving drum of the engine, the cable is quickly drawn in, the log is snatched off the ground in an instant, swung over the car, and lowered in place. In the deeper stretches of the forest the Russel road-locomotives are used to haul the logs out to the tracks, where they are loaded on broad wagons fitted with wide-tired wheels. One road-locomotive of fifty horse-power will haul from fifty to one hundred tons, loaded on a train of wagons, over

any kind of road, and uphill as well. Competitive influences in the lumber business have made necessary the use, wherever possible, of machinery, that was unknown in the old days. Smaller pay-rolls, reduced feed-bills, and more logs are the results sought for to-day.

"After man's arm has levelled our forest giants, let modern methods do the rest," reasons the old timberman, "for, why waste time and labor in hauling these countless tree-trunks to the car or roadway?" He knows that at a fraction of the expense the logs may be whisked over the ground by a simple appliance of steam power, and, with few helpers, may be lifted to any height in a jiffy and stacked on the car. But the modern log-loader, combining the operations of a switching engine and skidder, will do much more than this. A loader mounted on its own drivers handles itself and the empty and loaded cars as well as the logs; with this power of self-propulsion with increased utility, it is entirely independent at all times and under all conditions. Its economy of operation is surprising as only four men are needed to snake out and load from 100,000 to 125,000 feet of logs a day.

In examining this hoisting-machine it will be seen that the main frame and legs are of steel construction throughout, of eight-inch I beams thoroughly braced, fitted, and riveted together. During hoisting operations the legs, terminating on broad shoes, rest solidly on the ties outside the rails, and, with the wide strong frame above, form a rigid and secure foundation for the hoisting-machinery and boom. To afford protection to the machinery, the cab is enclosed on the sides and rear with matched pine ceiling, while the front is provided with a full-length roll canvas curtain. The floor is of two-inch matched pine, and the top is covered with corrugated iron roofing.

The power consists of a double-cylinder hoisting-engine with two bronze-bushed friction-drums, ample boiler capacity, and proper pipe connections. All the gearing is of steel, and is solidly attached and fitted. There is a

LOGS AS DECKED AND SKIDDED WITH FOUR-LINE SKIDDER ALONG SPUR OF MAIN LOGGING ROAD

CLYDE FOUR-LINE SKIDDING MACHINE IN OPERATION IN NORTHERN MICHIGAN
(SKIDS AND DECKS 150 M. PER DAY)

water tank hung back of the boiler made of white-pine staves, jointed, with adjustable steel hoops, and fitted with the necessary siphon and connections, including suction hose and strainer for filling tank. The hoisting gear is composed of heavy swivelled boom-blocks; and all necessary fittings and attachments are of an approved type, including a patent quick-return device. The guy-lines are ⅞-inch steel wire, and the steel-wire hoisting-cable is ⅝-inch, fitted with hook, pull-down ropes, crotch-lines, and four bunch-chains.

Probably the most interesting feature of the machine is the propelling-gear. There are four special driving-wheels twenty-four inches in diameter, with deep flanges pressed and keyed to axles five inches in diameter. Connections to engines are heavy steel sprocket-chains running on heavy long-tooth sprockets keyed to the shaft. The brake operates on a band wheel on main driving-shaft. When in position for hoisting and switching operations, the propelling-gear is raised clear of the track about six feet, so as to permit the passage of the empty cars to be drawn into place for loading.

After hauling its train of empties up to the first skid-way, ready for placing and loading the first car, the wheel legs are swung outward and upward, the power being transmitted by means of a worm-gearing to the cables running over the extended sheaves. The wheels remain in any position without locking, thus guarding against any possibility of the car settling when the wheels are partially extended, or from their dropping after the trunks are swung up horizontally. About half a minute is required to lift the wheel-legs to position.

The spotting-cable is then run under the machine and back to the second car of the train, and the cars are pulled forward until the first one is in position under the boom and ready for its load. When loading regular flats, after the front end is loaded, the car is hauled forward so that the rear end may receive its share of logs, and so on

through the whole string. The arrangement of the double sheaves at top of boom permits of two lines being used, which take care of the logs on both sides of the track at the same time. Separate drums control each line; and while one line is being hauled in on one side, the other line is being run out on the other side. Logs from a distance up to a thousand feet or more may thus be economically skidded, and much quicker than it could be done by horses. In skidding, double hooks very much like the iceman's tongs are used; they grasp the log at one end, drag it through the woods, and lift the end over the car. After being hooked in the centre, the log is at once hoisted by the same cable; thus the operation is continuous and all delay is avoided. An operator skidded a log scaling over two thousand feet a distance of five hundred feet, over rough ground, and loaded it in fifteen minutes.

In loading from skidway beside the track, the logs are hooked at both ends, as they are more easily guided, and the log is lowered on an even keel, without the usual juggling acts with a log in mid-air. Where the logging-road runs across low and marshy ground, with the rails laid on timber supports or embankments, the loading operations are not restricted in any way. In fact, the machine will skid and load logs where teams could not do the work at all. In loading small timber, bunching-chains are used by passing them under the ends of a number of logs, and, instead of ten separate lifts, one strong one does the work. Another economy resulting from the use of the steam log-loader is the possibility of loading standard flat cars to their full capacity, which is seldom done when the old methods of horse and man power are employed. In loading heavy timber of large diameter, the work goes on faster than with smaller logs, because fewer lifts are necessary; the average time required, including wrapping and fastening chains, is two and three-fourths minutes. Experience has shown that

one machine operated by a skilled engineer, who sets the pace for the other workers, will do the work of three crews of team loaders; in the case of hardwood it increases the scale of load from seventeen hundred feet (with horses) to twenty-four hundred feet. The average loads are fifty cars a day. Here is where reduced pay-rolls come in.

But the traveller, who has crowded so much of enlivening interest into the short winter day, is not through with his quest of unfamiliar scenes. He returns to camp as the tired workers — the forest invaders — troop in from the tote-roads, and, after a hasty supper of the same coarse though nourishing fare, he catches the last logging train out of the forest that night. He is following the shaggy logs to see what becomes of them, and to watch the amazing processes of present-day mechanical giants, by which the clear resinous pine is converted first into lumber and then into little lighting tapers, the common parlor matches. The progress of the train, with its heavily loaded cars, is slow and tedious, for there are numerous stiff grades to climb, and waits on sidings to permit upbound trains to pass. The main line of a logging-road carries much traffic in the rush time of the dead of winter. It was late at night when the puffing engine drew the string of cars into the boom siding on the shores of the little bay, near the match-timber sawmill.

Early in the morning the traveller is about and sees the logs being dumped from the cars, down short skidways into the log boom, and watches the boomers pole them into the mill boom just beyond. In an endless procession they are hurried on, and it is only a matter of an hour or so ere they reach the log end of the mill which is eating up their fellows at a lively rate. An endless chain of chaplets, dipping beneath the surface of the pond, catches the logs as they are poled into place, and in a jiffy they are drawn clear of the water and up the smooth ways into the mill. On the upper floor, where the big band-saw and numerous small circulars are buzzing

wickedly, the chain stops an instant, and the log is rolled off on an inclined way, very near and ready for the saws.

The sights and sounds and smells, which are almost terrifying to the visitor unfamiliar with such places, are, nevertheless, interesting and novel, and he is impressed with a sense of wonder at the intense activities and system of the great industry. The long saw-carriage rushes back and forth, back and forth, with its load rapidly changing from log to lumber, and every now and then it stops to take on a fresh stock for the voracious saws. The log is rolled on by steam "niggers," which are steel-shod rods thrust up through the floor of the inclined way, and the log is secured by "dogs" on the log carriage. In two minutes the log has been cut up, the lumber has been trimmed, and is on its way by automatic carriers to the piling ground, for seasoning. The edgings meanwhile are being cut to convenient lengths for cordwood. Near the farther end of the mill is a huge gang-saw which, with its multiple saws, transforms several square timbers into planks so quickly that the visitor can scarcely realize how it is done. In a corner the lathing saws are noisily working up the refuse into laths. The sawdust and small slabs go on endless conveyors to the fire-room where it is delivered to the furnaces or to the refuse consumers. Nothing in the way of wood that is of the slightest value goes to waste; some of the refuse, which is to be used for kindling-wood, is loaded on cars and shipped to the city wood-markets.

The quantity of matchwood used every day for lighting purposes is enormous; the figures representing the total are almost beyond belief. An expert in forestry has determined after careful computation that the civilized nations of the world strike three million matches every minute of the twenty-four hours. These figures may appear staggering, and to some people it may seem incredible that nearly half of all matches used are lighted in the United States. Doubting ones have only to remember

how smokers of pipes are tantalized by the going-out habit of their "smokes." The Forest Service has a practical object in putting forth statistics, in order to draw attention to the rate at which the insignificant little match is eating into the diminishing forests of the country.

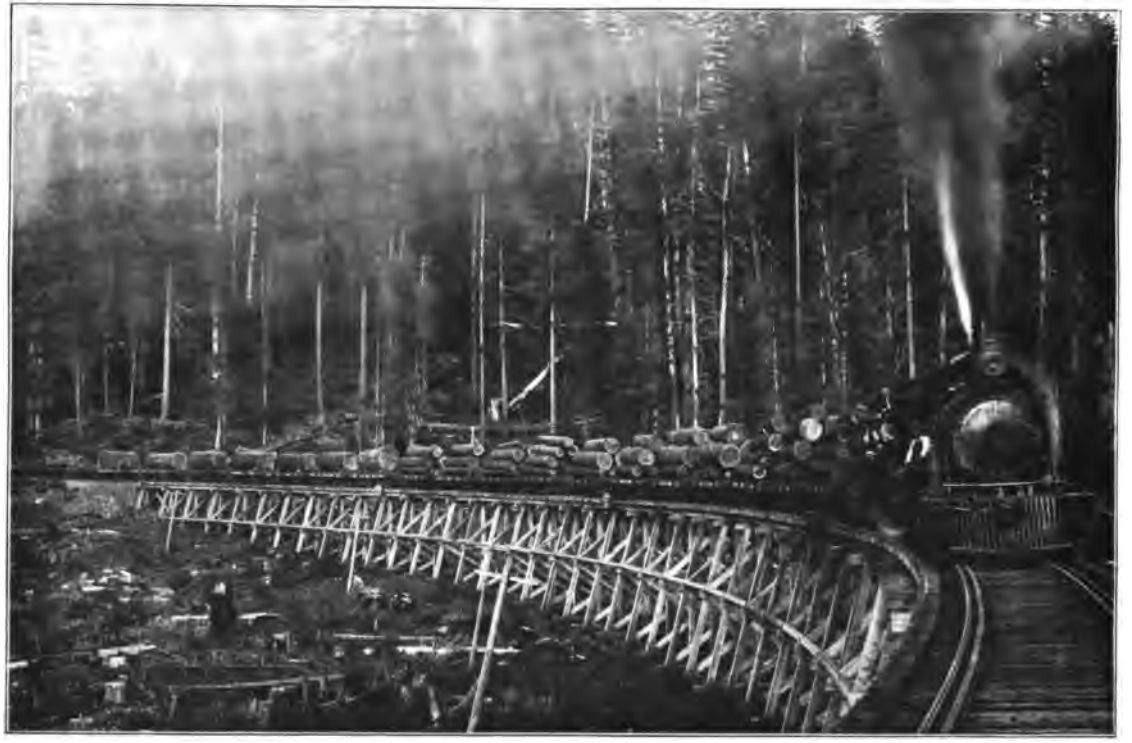
The relation that forests bear to the prosperity of the people is very imperfectly understood by Americans; until very recently they have paid little attention to the influence of the forest reserves in regulating the flow of streams and the recurrence of floods; nor have they given much thought to the effect of their depletion in the creation of desert wastes, with the resulting decay of nations. We forget that Palestine, before the destruction of the forests of Lebanon, supported a population of ten million in affluence, and that to-day scarcely four hundred thousand people remain, and they are in abject poverty. The valley of Babylon, once proud and prosperous, is now abandoned and forlorn; while the sites of Carthage, Tyre, and Sidon, once prosperous, fertile, and blessed with abundance, are now covered by desert wastes. That such conditions may not be repeated in this country, the American Forestry Association is devoted to the perpetuation of our natural resources through intelligent use.

The American people use the enormous total of seven hundred billion matches a year; but a statement of the number of cubic feet of wood actually converted into matches conveys a very indefinite idea of the number of trees required for the industry. It is the general belief that matches are the by-products of planing-mills and other wood-working factories, but, as a matter of fact the best grade of two-inch lumber is used for matches, while sashes, doors, and blinds are the by-products of the match-timber sawmills. In a single year the Match Trust cut two hundred and twenty-five million feet (board measure) of pine in the Great Lakes region; and one of the one hundred and fifty or more factories uses two hundred thousand feet of sugar or yellow-pine logs every day. The

deduction is that, in common with other industries of the United States depending upon existing forests, the match-makers are within sight of a shortage in the wood supply. When the present timber holdings have been depleted of match-timber, they cannot be duplicated in a generation; and the people of this country may have to get along with fewer than twenty-five or thirty matches a day each, as at present. In their insistent way, they will probably demand that the practice of Germany and France be followed, that foresters plant and grow timber especially for matches. This could readily be done if forests were placed under management, and were no longer left to run wild and produce cordwood and brush, instead of merchantable timber.

Away back in the beginning of the Christian era, Pliny, in his "Historia Naturalis," recorded the use of flint and steel for lighting tinder, and ascribed to Clias the name Pyrodes, as the first to show its practical application to useful purposes. For centuries the striking together of these metals was the only means of obtaining flame. From the history of later times we learn of the use of the bow-drill, the point of which revolving rapidly, back and forth on hard dry wood, produced by the friction thereof much heat and after a time a tiny spark which was caught in dry moss; more recently, by means of a brimstone splint and tinder, a flame was easily obtained, and this method is still in use by the Eskimos and other semi-barbarous peoples.

Within the memory of our grandfathers, at a time when inventions were few, the lucifer match came into popular use, and was soon followed by the Congreve match. The vesta, a short thin wax taper with slightly different igniting composition, was the forerunner of the safety kind of to-day, which is struck only on the box. Although the present making of flame, and putting it out for economic reasons, was not practised in the olden times, fires were kept in a smouldering state for hours to strike the flame



LOGGING TRAIN ON MAIN LINE IN HEART OF THE FOREST

anew. It is little wonder, then, that our ancestors hailed the invention of the lucifer match as one of the foremost discoveries of the time.

The first match with an igniting head was made in 1825, and the little one-story house in which it was made still stands. The "old match house," as it is called, occupies a prominent place in Main Street, near the centre of the mountain village of Thurmont, which lies nestled at the foot of a spur of the Blue Ridge Mountains in Maryland, and only about sixty miles north of Washington. Joseph and Jacob Weller were the first makers of lucifer matches; their process was slow and laborious, each splint having to be cut by hand and dipped separately in the composition which formed its head. Not until recent years have improvements over these crude methods revolutionized match-making, thus reducing the cost of production, so that now a hundred matches may be had anywhere for a penny. This result was not brought about in a moment by the inspired idea of some genius, or without much experimenting by practical men. Many months and even years were spent in perfecting the modern methods of match-making, and a great system and wonderful machinery now control the match industry.

Until a very recent date, the splints were made of veneer pared from basswood logs or other soft woods. At the farther end of the match building, beyond which is the log yard piled high with sound, well-seasoned timber, we find men busy at the huge veneer-cutter, and are interested in watching the five-foot section of log being pared up into wide thin sheets, the exact thickness of a match. The log, after being passed through a steaming process which softens the wood, is grasped firmly at the ends as in a lathe, and revolving, comes in contact with the sharp edge of a long knife held securely in a stiff frame which moves ever so slowly but positively toward the log, thus producing the long thin sheet of wood. These strips are cut to convenient lengths and bunched

one over another so as to pass evenly under the knives of the splint-cutter. The knives of this simple machine have eight splits at intervals of the exact length of a match, so that with each downward stroke (and there are one hundred and fifty strokes a minute) the splints are cut and fall into a receiver. From here they are dumped into an immense drum provided with netting, which revolves within a chamber through which a blast of hot air passes. The splints are thus thoroughly and quickly dried, and at the same time the small splinters are removed by friction, leaving the match splints smooth and white.

The splints are then placed in a tray shaker, which in a moment brings them into line side by side, with the precision of a regiment of soldiery, when they are ready for the sticking-machine. This is a wonderfully simple device, which forces the splints into perforations in dipping plates, so that they are held securely during the following processes. The plates are placed with the splints downward, one after another on a bed of a moving endless chain, which carries them over a tank containing paraffin, and a little further on over a roller covered with the igniting composition. The plates are then placed in racks for the match-heads to dry.

During all these operations we are impressed by the smooth working of a perfect system, each and every operator being trained to his specialty. All his movements this way and that, the lifting of an arm, or the touch of a hand, count in the run — the final output of the plant. There are no false moves, no confusion, and no rush. Only a uniform systematic effort and an honest one, to turn out perfect matches. While standing with the workers in the midst of the whirl and grind of the machinery, we are informed that the latest advance in match-making, a machine showing as great an inventive genius as any achievement in the mechanic arts, is yet to be seen. When told that two of these machines are producing thirteen million matches daily at a saving of fifty per cent over

the processes just witnessed, one naturally is eager to know how such things are done.

To what extent cold steel can be made to do the work of brawny arms and nimble fingers actuated by active brains, is clearly shown in the operation of the new automatic match-making machines. Imagine, if you can, a long narrow machine, occupying a space ten feet by thirty feet and twelve feet high, which produces every minute of the work day twelve thousand matches, boxed and ready for shipment. For every hour the capacity is seven hundred and twenty thousand matches, and for the day of ten hours it amounts to seven million two hundred thousand. The most interesting feature of the machine is its automatic operation, every separate step in the process being nicely regulated, so that from the block of wood to the finished matches piled on the packing table, no one touches the product. With this machine cork pine is used for the match timber. The two-inch planks are hauled from the seasoning yard of the sawmill and cut up into blocks of exact match-lengths, much care being taken to cut out all knots.

The blocks are thrown into crates mounted on small trucks, and wheeled to the cutting end of the machine. The blocks are fed into one end of it through a block-conveyor and come under a battery of forty-eight wonderful little circular knives, which gouge down lengthwise of the grain and come up each bearing a match splint. They make two hundred and fifty strokes a minute, cutting twelve thousand splints. A shelf slides under the row of splints and, with each upward stroke of the knives, forces their upper ends into perforations in a steel bar which is one link of an endless belt, five hundred feet long. The splints are held securely in the bars, and the long journey of fifty minutes around the circuit of the belt is begun.

A short distance from the knives the ends of the matches pass through a paraffin bath, which makes them more in-

flammable. The paraffin is kept in a liquid state through an ingenious contrivance by which, as it cools, it is drained off and a fresh supply of a much higher temperature is automatically added. Beyond this are two tipping rollers. The matches principally made are the double-tipped or noiseless kind, the phosphorous friction material and the chlorate of potash composition being put on separately. Each of these is kept melted in a reservoir in which a roller turns at exactly the same circumference speed as the belt bars are moving above it. The roller brings up the material to the tips of the match splints as they are brought by on the belt. Considerable space elapses between one dip and the next, allowing time for the head to dry.

The matches are then carried over a series of reels, bringing them into various positions to allow the pasty tip material to form a round head. The rest of the length of the belt is for the purpose of allowing the matches to become perfectly dry. Just before the belt comes back to the starting point, the matches are punched out of their bar holder, by a row of pins, one fitting each hole in the bar. Falling on a shelf, they are conveyed on an endless chain to the packing table, where they are picked up by girls and placed in boxes, which are wrapped and sent to the shipping room. Including the five packers, seven persons are required to attend the machine, doing the work which in the older processes required about twenty-five for less capacity.

In another room in the front of the factory, boxes are made by automatic machinery, the operations of which are only slightly less interesting than the match-making department. The box-board comes to the factory in large rolls and these are cut to the widths required for the various sized boxes. The box-board is fed into one end of the box machine, where it is cut into the right shape and size, after first being printed with the name and brand of the company. A strip of sand is put on one side by

passing the surface over a roller covered with glue, to which the sand clings when thrown up against it by an ingenious device a few inches farther on. The one long narrow machine does all these operations, only two operators being needed to carry away the boxes and watch the machinery.

The new automatic machinery, requiring so few operators, has already effected a saving to the consumer, if a saving it can properly be called. For, with the price of one penny for a hundred matches, one could scarcely appreciate the new box of the company, containing eight hundred for a nickel, but for the marvel that so many matches may be had for so little money.

In the pioneer days of lumbering in the north woods the old lumber barons did not trouble themselves very much with bookkeeping or accounting. There was little need of it. They were reaping where they had not sown; and the trackless forest, which Nature in her bounty had been creating for centuries before, needed only the slaughtering though wasteful hand of man to be turned to gold. Those were the good old days when fortunes were often turned up over night, when operators and habitants of the northern wilderness awoke to find riches in easy reach. Large tracts of virgin forest, which to-day would be worth millions, changed hands for sums which were a mere bagatelle; and in some cases the timber was stolen outright.

Under the then existing conditions of barter and trade, all transactions represented an actual exchange of commodities, or of material for coin; and for exceptions to the general rule, the memory served in lieu of bookkeeping. It is related that some loggers as a precaution used ordinary school slates to scribble a hasty record of important deals. When the obligation was paid, a rub with the hand erased all tangible evidence of it, and left the surface clean for subsequent entries. Later, a sort of pocket diary served the camp boss, and was followed in

the natural order of events by a printed time-book and scale book and a few blank books. The foundation of many a fortune made in the Michigan woods is shown in the leaves of a blotter such as may be found in any meat shop.

The intricate accounting and cost-keeping of to-day were unknown arts, but they would scarcely have been used anyway. The lumbermen concerned themselves little with the cost of operations. The profits were large and they generally were getting rich. Why should they bother with knowing the cost to a fraction of a cent of felling a tree, the skidding of it, or the dumping of it into the stream. There would have been little satisfaction in having condensed reports of the log mile, the saw duty, the net profit of the "van" (camp store), or the team day. What actually counted to the old-timers was the result of the season's run. If their pockets bulged with money and were heavy with coin, they had had a profitable year. Or upon a larger scale, a bank account in which the dollars were set down in less than five or six figures was certain evidence of a lean year.

According to the latest advices from Western lumber barons the value of the lodge-pole pine, or tamarack, is now being recognized, and a valuable product of the forest is at last coming into its own. The lodge-pole pine gained its name from its wide use by the Indians as a support for their tepees. Since the Indians of the Rocky Mountains dragged their lodge poles to the plains when on hunting trips, a timber of requisite height for smaller diameter was sought, and this the lodge-pole pine provided without trimming. The names white pine, black pine, spruce, and tamarack are also applied locally. In Wyoming lodge-pole pine is more numerous than any other tree, and it is largely represented in the forests of Colorado, Utah, Montana, and Idaho, and to some extent in Washington, Oregon, and California.

It grows from sea level to eleven thousand feet eleva-

tion, and is noted for its variable form and quality. In the Rocky Mountains the wood is lighter in weight and color, less resinous, and straighter grained than on the Pacific coast. Lodge-pole pine attains an age of from one hundred to three hundred years. It quickly succumbs to fire on account of its thin bark, but to a certain extent guards against extinction by this cause, by producing fertile cones at the early age of from six to ten years. Reseeding after a fire is favored also by the persistence of the cones, some of which do not shed their seeds for a number of years, and the readiness with which the seeds germinate on mineral soil of burned-over land. A large proportion of the seeds germinate; they are usually borne annually in large quantities; and since they are small and light they are carried by the wind as far as two hundred yards from the seed tree.

The yield runs as high as twenty thousand board feet per acre, though it does not often run over seven thousand feet. The tree is of small size, seldom exceeding eighteen inches in diameter and ninety feet high, but it usually forms dense stands. It is valuable for poles, hewed ties, mine props, stulls, logging poles, converter poles and box boards. The demand for it for hewed ties is especially strong for two reasons; the wood hews easily, and, since the common size of the tree is from eleven to fourteen inches in diameter breast-high, there is little hewing to be done. Experiments on a large scale looking toward the use of lodge-pole for paper pulp, will be tried by the purchasers of the timber from one of the national forests. The rate of growth is very slow after the first few years.

Three of the largest timber sales from the reservations are of lodge-pole pine. One of one hundred and sixty-five million board feet is in the Medicine Bow National park, on the Colorado-Wyoming line; one of fifty million board feet in the Big Horn forest, in Wyoming, and one in the Hell Gate forest, in Montana. In the latter sale the

saw timber brings four dollars per thousand feet, and the converter poles ten cents each. Cordwood is also included in the contract, so that every stick of the timber marked for removal down to two and a half inches, is taken. Utilization is almost as complete as in a German forest.

The best authorities on the subject, men who have travelled through the tracts, assert that the principal associating trees are Douglas fir, Engelmann spruce, western white pine, and western yellow pine, occurring in some places with lodge-pole pine. The Douglas fir decreases, and the Engelmann spruce increases in the mixture, going south from the Montana line through Wyoming, Idaho, and Colorado.

Lodge-pole pine grows a little taller on an average in Montana than in Wyoming, a twelve-inch tree in the former State having a height of seventy-four feet, and in Wyoming sixty-nine feet. The growth is very slow in all localities, though a little faster in Montana than in Wyoming. In a hundred years the average diameter in Montana is eleven inches and in the latter from seven to ten inches. A sixteen-inch tree sixty feet high contains one hundred and sixty board feet, Scribner scale; eighty feet high, two hundred and thirty feet; and one hundred feet high, three hundred and fifteen feet board measure. The bark is very thin, trees over eight inches in diameter having only six per cent of their entire volume in bark. The solid contents of a sixteen-inch tree sixty feet high is about forty and one-half cubic feet; but if eighty feet high it is forty-eight cubic feet. For each cubic foot of volume a six-inch tree will produce five and six-tenths board feet, the factor rising to six and five-tenths board feet per cubic foot in a twenty-two-inch tree. An average of two hundred and twelve twelve-inch trees cut for ties showed the following number of ties for different heights: Sixty feet, 3.2 ties; seventy feet, 3.5 ties; eighty feet, 4.1 ties; ninety feet, 4.5 ties, besides consid-

erable material for mine props, cut from the tops. In a stand averaging seventy feet in height, a twelve-inch tree will contain a forty-foot pole and a seven-inch top; a sixteen-inch tree will contain a fifty-foot pole; and a twenty-inch tree will contain a fifty-five-foot pole.

Thirty-eight years ago lodge-pole pine was cut for railroad ties in southern Wyoming. Only the best trees were taken, and the trees left are now approaching merchantable size. By the settlers, lodge-pole pine is used for many purposes, especially for house logs, fuel, and fencing. Because of its tendency to decay when set in the ground, fences are built on top of the ground and braced; thus the life of the post is increased from five to fifteen years. Preservative treatment is now introduced, which will greatly enhance the value of the wood for posts, telephone poles, ties, and mine supports. Railroad companies are already treating ties on a large scale at Laramie and Sheridan, Wyoming.

The rapidity with which eucalyptus trees attain merchantable proportions when planted and cultivated under right conditions, is an absorbing subject to all the people of the country who realize the tremendous problem of reforesting the barren wastes in almost every State of the Union. Of course the climate, soil, water, and care influence the growth of the trees to a great extent. When trees are planted in a haphazard fashion and left to grow by themselves without care, they do not attain large size so quickly as trees which are irrigated and cultivated during the dry season. Gifford Pinchot has pointed out the remarkable adaptability of the California climate and soil to the growth of the eucalyptus, which is a native of Australia and the adjacent islands. The reason for its peculiar liking for arid and semi-tropic California is plain. The eucalyptus will thrive and make an amazing growth with a minimum amount of rain and other moisture; and when grown, it becomes extremely valuable as timber. Is it any wonder, then, that these being the conditions —

ease and rapidity of production and great value of the product — the forestry idea in the Pacific State is centred in the eucalyptus?

There are about one hundred and fifty varieties of eucalyptus, most of which are of large size. They are all evergreens of vigorous growth, some of them growing five times faster than any other tree. In some instances trees twenty-five years old are as large as oaks from two hundred to three hundred years old. The close-grained wood produced from them has brought them into popularity and made them much in demand for all purposes for which hardwood is used. In growing, they serve as forest cover to mountains, hills, plains, and swamps, and as windbreaks and shade trees. When cut, they furnish valuable timber, excellent fuel, and a very useful oil. And one need not wait a lifetime to realize handsome profits from eucalyptus growth. The timber enters into the construction of buildings, ships, bridges, railroads, piers, telegraph lines, fences, paving, vehicles, agricultural implements, furniture, and a variety of minor articles such as barrels, casks, broom and tool handles, and pins and insulators.

The wood of the eucalyptus is extremely tough, and for this reason is especially adapted to bridge timbers, railroad ties and vehicles generally. Other American hardwoods cannot compare with it when put to the test. Next to XXX hickory, it is slightly less flexible under the earlier strains, but surpasses it before the breaking-point is reached. The wood is hard and firm, does not split, check, warp, crack, or sliver when it has been properly prepared; that is to say, when it is seasoned with the same attention that is given to other hardwoods. Some varieties are also suitable for interior finish and trim, such grades being imported under the name of Australian mahogany; they are worth from one hundred and twenty-five to one hundred and forty dollars per thousand feet for selected lumber. It is the principal source of supply for

the interior finish of Pullman cars. When used for flooring, it is of unusual beauty, taking a very high polish resembling onyx, and wears like iron.

In the manufacture of furniture, the eucalyptus presents no greater difficulties in handling than any other hardwood, and fills every requirement for cabinet work. It takes a high piano finish, or a dull finish, shows its grain to perfection, and takes any color or stain desired. It works up solid or in veneer, the same as any other desirable hardwood, and does not open at the joints when properly seasoned. The manufacture of veneer in the last few years has grown by leaps and bounds, and ere long the beautiful red gum or red mahogany — the eucalyptus of the Pacific — will come into more general use in this form. The best veneer is sawed, but a great deal is sliced, and still more is "rotary cut." By the last-named process logs of the desired wood are steamed until quite soft, and then fixed in a lathe-like machine, in which they are turned against a sharp knife. This is practically the same process as that by which the soft basswood logs are cut up in the making of match splints. As the log rotates against the knife, veneer of any desired thickness is peeled off in a continuous slice, as one pares an apple, going deeper and deeper at each complete turn, until nothing but the core is left. Some waste occurs in any process of making veneer, but in the rotary the resulting core is used for pulp wood, fuel, excelsior, crates, boxes, and baskets.

The varieties of eucalyptus grown in California are the red gum, blue gum, and the sugar gum; the first named is in greatest favor because of the larger uses to which its timber may be put. The profits, as figured on the culture of this great tree, are cheerfully amazing. The rule, as adopted by authorities in tree-culture, is to plant the trees eight feet apart each way. An acre of ground being two hundred and nine feet square, will, therefore, hold twenty-six rows of trees with the same number of trees in each row, or a total of six hundred and seventy-six

trees. At the end of two years there will average five hundred sturdy seedlings to the acre; and the most moderate estimate made of the value of a tree at the end of the sixth year, is six dollars. Each tree in the tract will produce a pole on an average of thirty-five feet in length and six inches in diameter, the value of which is above the price stated. Foresters, however, advise the holding of the timber for at least four years longer, when the trees have attained the age of ten years. At that time the larger and better trees will have reached a diameter of two or three feet and a height of from one hundred and twenty-five to one hundred and fifty feet. Such trees will yield timber to the value of twelve to twenty dollars each, taking no account of the waste and refuse which are valuable in that country. There are trees near Bakersfield thirty years old which would bring two hundred and fifty dollars on the stump for the timber they contain. At that rate, thirty years after planting, one acre of eucalyptus trees would be worth one hundred and sixty-nine thousand dollars.

And the first cutting is not all and the end of the profit-producing value of the tract. When cut down these trees reproduce two trees of equal or greater size from the stump where one formerly grew, and in one-fifth less time, therefore, such a tract will produce from two thousand to two thousand five hundred dollars a year for generations. Given the land and some extra help at planting time, and one man and a team can care for one hundred acres of growing eucalyptus trees. A little mental calculation will give results to be obtained at the end of any given term of years for the acreage employed. There are, however, land concerns which sell to the investor small tracts of five acres or multiples of five, already planted to the red gum or red mahogany, and which agree to care for it until of marketable proportions, guarding against fire, and giving proper cultivation and irrigation at all times of the year.

The yearly tribute of the nation's forest resources to the timber barons through their invading forces is enormous, and far exceeds the annual growth of all the standing timber in the United States. When it is considered that thirty-one thousand two hundred and thirty-one sawmills were in active operation during 1908, and the average cut of each in a busy year (1907) is one million four hundred thousand, one can only wonder how long the ravages will go on. The State of Washington is the largest producer, closely followed by Louisiana. A good way down the scale comes Mississippi, and then Arkansas, Wisconsin, Texas, Michigan, and Oregon, in the order named, but quite close in point of production. There follow Minnesota, Pennsylvania, Virginia, Alabama, North Carolina, West Virginia, and California, the group producing one billion feet or more. In Washington nearly all the lumber cut is of Douglas fir; while in Louisiana the cut is yellow pine and cypress. The production in Michigan, which has been decreasing steadily, fell in 1907 below the two-billion-foot mark for the first time in nearly forty years. That State, however, in the twenty-seven years following 1880, cut nearly one hundred billion feet, a production which has not been equalled by that of any other State. The output of Wisconsin during that period was at least seventy-five billion feet.

The Bureau of the Census of Manufactures, 1908, gives the appended table of the number of mills reporting, and the quantity and value of lumber, lath, and shingles produced in the United States, 1900 and 1904 to 1908:

YEAR	Number of mills reporting	LUMBER		LATH		SHINGLES	
		Quantity (M feet B. M.)	Value	Quantity (thousands).	Value	Quality (thousands)	Value
1908 ...	31,231	33,224,369	$510,575,822	2,086,684	$ 6,791,328	12,106,483	$24,178,490
1907 ...	28,850	40,256,154	966,641,367	3,663,602	10,342,705	11,824,475	30,111,337
1906 ...	22,398	37,550,736	621,151,388	3,812,807	11,490,570	11,858,260	24,154,555
1905 ...	11,666	30,502,961	445,343,231	3,111,157	7,777,892	15,340,909	26,380,682
1904 ...	19,127	34,135,139	435,708,084	2,647,847	5,435,968	14,547,477	22,009,610
1900 ...	31,833	35,084,106	390,489,873	2,523,998	4,698,909	12,102,017	18,869,705

The following table shows the same products, with the per cent of increase and of distribution, by States, 1908 and 1907:

STATE	Rank, 1908	NUMBER OF ACTIVE MILLS REPORTING		QUANTITY (M FEET B. M.)		Per cent of increase	PER CENT DISTRIBUTION OF TOTAL CUT	
		1908	1907	1908	1907		1908	1907
United States	.....	31,231	28,850	33,224,369	40,256,154	[1] 17.5	100.0	100.0
Washington	1	929	1,036	2,915,928	3,777,606	[1] 22.8	8.8	9.4
Louisiana	2	516	531	2,722,421	2,972,119	[1] 8.4	8.2	7.4
Mississippi	3	905	823	1,861,016	2,094,485	[1] 11.1	5.6	5.2
Arkansas	4	1,155	1,146	1,656,991	1,988,504	[1] 16.7	5.0	4.9
Wisconsin	5	899	778	1,613,315	2,003,279	[1] 19.5	4.9	5.0
Texas	6	605	673	1,524,008	2,229,590	[1] 31.6	4.6	5.5
Michigan	7	989	906	1,478,252	1,827,685	[1] 19.1	4.4	4.5
Oregon	8	595	644	1,468,158	1,635,563	[1] 10.2	4.4	4.1
Minnesota	9	500	429	1,286,122	1,660,716	[1] 22.6	3.9	4.1
Pennsylvania	10	2,224	2,131	1,203,041	1,734,729	[1] 30.6	3.6	4.3
Virginia	11	1,937	1,652	1,198,725	1,412,477	[1] 15.1	3.6	3.5
Alabama	12	981	892	1,152,079	1,224,967	[1] 6.0	3.5	3.0
North Carolina	13	1,740	1,668	1,136,796	1,622,387	[1] 29.9	3.4	4.0
West Virginia	14	1,044	1,044	1,097,015	1,395,979	[1] 21.4	3.3	3.5
California	15	288	321	996,115	1,345,943	[1] 26.0	3.0	3.3
Maine	16	902	927	929,350	1,103,808	[1] 15.8	2.8	2.8
Georgia	17	1,049	788	904,668	853,697	6.0	2.7	2.1
Tennessee	18	1,490	1,104	790,642	894,968	[1] 11.7	2.4	2.2
New York	19	2,291	2,185	781,391	848,894	[1] 8.0	2.4	2.1
Florida	20	279	302	730,906	839,058	[1] 12.9	2.2	2.1
Kentucky	21	1,530	1,451	658,539	912,908	[1] 27.9	2.0	2.3
New Hampshire	22	604	544	606,760	754,023	[1] 19.5	1.8	1.9
South Carolina	23	423	365	560,888	649,058	[1] 13.6	1.7	1.6
Idaho	24	255	247	518,625	513,788	0.9	1.6	1.3
Ohio	25	1,094	987	459,259	529,087	[1] 13.2	1.4	1.3
Missouri	26	1,108	916	458,938	548,774	[1] 16.4	1.4	1.4
Indiana	27	1,089	999	411,868	504,790	[1] 18.4	1.2	1.3
Massachusetts	28	610	518	384,526	364,231	5.6	1.2	0.9
Montana	29	173	130	311,533	343,814	[1] 9.4	0.9	0.9
Vermont	30	596	612	304,017	373,660	[1] 18.6	0.9	0.9
Maryland	31	384	307	168,534	213,786	[1] 21.2	0.5	0.5
Oklahoma	32	214	129	158,756	140,015	13.4	0.5	0.3
Connecticut	33	293	236	137,855	140,011	[1] 1.5	0.4	0.3
Illinois	34	546	499	133,319	141,317	[1] 12.7	0.4	0.4
Colorado	35	254	230	117,036	134,239	[1] 12.8	0.4	0.3
Iowa	36	113	100	97,242	144,271	[1] 32.6	0.3	0.4
New Mexico	37	61	52	79,439	113,204	[1] 29.8	0.2	0.3
Arizona	38	11	12	43,287	72,134	[1] 40.0	0.1	0.2
Delaware	39	112	106	41,184	50,892	[1] 19.1	0.1	0.1
New Jersey	40	181	166	34,939	39,942	[1] 12.5	0.1	0.1
Rhode Island	41	45	41	30,528	32,855	[1] 7.1	0.1	0.1
South Dakota	42	47	64	25,859	34,841	[1] 25.8	0.1	0.1
Wyoming	43	70	73	18,822	17,479	7.7	0.1	[2]
Utah	44	95	80	15,059	14,690	2.5	[2]	[2]
All other states [3]	.....	5	6	10,627	5,891	80.4	[2]	[2]

[1] Decrease. [2] Less than one-tenth of 1 per cent. [3] Includes Kansas and Nevada.

II

SALT

THE SALT OF THE EARTH

SALT AN OBJECT OF DESIRE IN ANCIENT TIMES AND MODERN — SALT MINES IN AUSTRIA AND ROUMANIA — THE DEAD SEA — DEPOSITS OF SALT IN UTAH — VARIOUS SOURCES OF SALT — DEVELOPMENT OF THE INDUSTRY IN AMERICA — COMPETITION IN SALT-MAKING DISTRICTS — COMPARATIVE PRODUCTION BY STATES — ECONOMICS OF SALT-PRODUCTION — METHODS OF MANUFACTURE — MICHIGAN THE LARGEST PRODUCER — ITS GREAT SALTWORKS — PARTICULARS OF THE PROCESS — CONNECTION BETWEEN SALTWORKS AND PLATE-GLASS MANUFACTURE — OHIO SALT-FIELDS — USES OF SALT.

ALL the world needs salt, and all peoples use it freely and for various purposes. It could scarcely be otherwise, since salt is a component part of the blood, for which reason it is considered necessary to the maintenance of animal life. It is one of the common products of the earth, both of land and sea, and has been sought for food from the earliest epochs of history. Ancient literature shows that there is an element of romance about salt. It was highly prized by the ancients, and was used as a sacrificial offering. The Jews offered it to Jehovah in covenants; Homer called it divine; and it figured in the banquets of the heroes. To many of the Orientals the substance is held as sacred even to this day.

Through all ages salt has been made an object of war and oppression. The possession of the natural sources of salt has always been attended with strife and bloodshed. Tacitus relates that the most bitter warfares waged by the ancient Germans with the Romans were in protection of their saline springs. Since then, many nations have fought for salt supplies. Even in modern times, within

the memory of present generations, the efforts made during the Civil War to destroy the salt-works of the South were sometimes successful. The most cruel exactions ever made were in the name of salt-taxes in France and other parts of Europe. In many countries, notably Austria-Hungary and Turkey, the salt industry has been a Government monopoly yielding large revenues. It is believed that Venice has owed much of her commercial supremacy to the control of the salt trade of southern Europe; and in more recent times Liverpool has benefited largely by her considerable control of the trade. To the Sudanese salt is the most valuable thing he can possess, and he is often driven by necessity to give anything that he has, even gold, for a lump of salt. A certain appreciation of the substance is shown when righteous people are spoken of as "the salt of the earth." That very good word "salary" is derived from the ancient Roman practice of giving the soldiers, as part of their pay, money to buy sal (salt).

Salt is known in chemistry as sodium chloride, and in mineralogy as halite. It occurs in nature as rock salt, large deposits existing in Austria, Spain, Germany, India, England, Ireland, Canada, and in several of the United States. Probably no process of salt-production equals in interest that of mining as carried on in Austria, the deposit of which has been traced along the base of the Carpathian Mountains for about two hundred and fifty miles. It has been open for mining at Wieliczka, Galicia, since the early part of the twelfth century, and may have been operated at a much earlier date. In the wonderful salt country around Ischl the mines are show places, and tourists are carried through them for a fee. In the valley of the Vistula, in Austrian Poland, there is an underground city hewn from rock salt. It was started a thousand or more years ago, and to-day it has winding streets, railway stations, churches, and restaurants.

The salt mines of this curious underground world com-

prise eight main pits, some of which reach to a depth of nine hundred feet, and sixty shafts of a combined depth of more than two miles. Strange as it may seem the present equipment of these ancient mines is of the most approved type. There are steam hoists, a special elevator for conveying parties of visitors down into the main passage, electric lighting plant, automatic drills, and mining railways twenty-two miles in length. The area of the mines and subterranean city is an oval, twenty-two miles in length and half a mile in central width, with galleries of more than sixty-five miles in extent. The enormous cavities dug out during the last century amount to one hundred and six million cubic feet, and are continually increasing in area. From the point of production the salt, as hewn out of the solid mass in blocks weighing about eighty-eight pounds each, is hauled by horse tramways to the nearest pit, from which it is conveyed on the railway to the main station. The fragments of salt resulting from blasting or the use of wedges are not wasted, but are worked up in a local soda-factory, or ground for table use. In recent years the mines employ about one thousand workmen permanently and many others at times. The working-time in the mines is eight hours a day; and twelve hours for those who work above ground; and the yearly production is 2,400,000 pounds. Nature has provided for adequate ventilation, and only in remote chambers is artificial ventilation necessary.

Roumania has four great salt-mines, three of which are worked by convict labor, and have been called the " white hell." One of the most wonderful sights a tourist sees is displayed when a guide lifts a trap-door above the marvellous cavern and shows him a great glistening field of white, hundreds of feet below, about which men move as mere dots of black. There are strange natural frescoes upon the walls, which assume all sorts of mysterious shapes, beautiful decorative patterns, impossible heraldic animals, or wild sea-serpents. The salt is hewn out from

the floor and sides in blocks, then crushed by hammers and sent on cars to storehouses above.

In the Holy Land, salt has been used as a medium of exchange, or currency, from time immemorial, the product being collected on the shores of the Dead Sea and brought to the Jerusalem market for curing hides and for domestic purposes. That great body of salt water, whose surface is thirteen hundred feet below the level of the Mediterranean, receives annually six million tons of water by rainfall, all of which is carried off by evaporation in the sweltering hot and dry air of this region. The water remaining is impregnated with mineral and other substances to the extent of over twenty-five per cent of which about seven per cent is salt. The natives obtain the salt near the mouth of the Jordan from the precipitated deposits beneath the surface of the sea, by diving, and are hence called "salt-divers." After a sufficient quantity of salt has been secured by evaporation in the open air, a long string of camels comes over the desert, the salt is loaded up into paniers, and the procession takes up its march over the dreary wastes toward the ancient city.

Salt often occurs disseminated through the soil, and in dry, hot regions it appears as an incrustation upon the surface. Many of the important discoveries of such beds as well as of other deposits, were mere accidents. A hunter tramping over what he considered a barren tract along the Salt Fork River, about thirty-five miles west of Enid, Oklahoma, kicked up a lump of salt. He found that wherever he disturbed the thin crust of earth over this waste land, he turned up more of the stuff. The area was uninhabited and unused and he made up his mind to enter the tract as a claim. Before he could carry out this plan, however, the Government heard of the find and sent representatives of the geological survey out to investigate. As a result the land was withdrawn from entry and set aside as a saline reservation. It proved to be the bed of a salt lake, long since dried up and of about thirty square miles

in area. Geologists assert that at least one hundred thousand barrels of good salt can be taken up without disturbing the ground beneath. One of the largest deposits of rock salt in Oklahoma was struck, in 1907, by a ranchman who was driving a well on the prairie in search of fresh water for his stock.

In blasting a tunnel on the west side of the Utah desert, not far from the Nevada line on the route of the new railroad from Denver to the Pacific coast, the workmen were surprised to find that the dynamite blasts uncovered an immense deposit of pure salt. An investigation showed that this singular find was fifteen miles long and ten miles wide; and if the sides of the tunnel are of sufficient strength to support the roof, trains will pass through glittering walls of whiteness for almost the entire length. Two boys fishing along the Kanawha River in West Virginia, filled a bottle with sparkling water that bubbled up in a spring near the river bank. When they drank it they were surprised to find it very salty. This led to an investigation and the discovery, by borings, of a natural brine-well extending down into a large deposit of rock salt. From this resulted the establishment of the first and most profitable salt works in the State.

When obtained in nature in a state of purity, salt is a colorless transparent solid, but it crystallizes easily and masses which have a vitreous lustre. When it is pulverized or obtained in crystalline form it is white, like snow. Rock salt is sometimes found in colored masses such as azure blue, red, and at times of other colors, the colorization in each case being due to foreign matter. These foreign substances are calcium, magnesium, potassium, sodium sulphate, iron compounds, minute quantities of bromides and iodides, clay, and bituminous matter; the quantities of these differing widely with the deposits. Salt is easily soluble in water, forming a saturated solution in the proportion of thirty-six and nine-tenths parts of salt to one hundred parts of water at sixty degrees Fahren-

heit. It contains twenty-six and forty-seven-hundredths per cent of salt, and has a specific gravity of 1.2055. The solubility increases but little with an increase in temperature.

A close study of the sources of salt is most interesting.

"Sodium chloride is constantly formed through chemical changes occurring in the mineral constituents of the earth's crust. Owing to physiological processes salt is constantly being eliminated by living animals, and with their death and decay a still larger quantity is yielded. The wind, blowing across bodies of salt water, carries salt-laden air overland, where the precipitating moisture bears it to the ground. This meteoric water dissolves additional soluble substances from the soil, but, meeting with argillaceous matter, the compounds which serve as plant food are precipitated out, while the common salt and the lime and magnesium compounds pass to the streams and rivers and eventually to the seas and oceans, where these salts accumulate. In some cases salt-bearing waters flow into landlocked depressions and form bodies like the Great Salt Lake of Utah. If such conditions as a high natural temperature, constant winds, a limited rainfall, and the absence of fresh-water feeders obtain at these localities, the saline water in such lakes, or in landlocked bodies of sea water, may become so saturated or concentrated that the common salt and its associated compounds are precipitated out, forming in time large deposits, and impregnating and incrusting the soil. This has happened about the lake at Salton, California, and elsewhere.

"In geologic time accumulations of precipitate salts, like those described, have been buried beneath the earth and formed into rock masses. Eventually subterranean streams of water have encountered them, and becoming, through solution, highly charged with salt, have issued at the surface as salt springs, or salt licks, which are also known as 'salines.' The meadow land about such springs or the intermittently overflowed land adjoining the ocean, seas, or salt lakes may, if the situation be favorable, become more or less impregnated with salt and form salt marshes.

"From all these sources — the oceans, the seas, the salt lakes, the salt marshes, the salt-encrusted deserts, the rock deposits, and the salt springs — man has gathered salt in the conduct of the industry. When ocean or sea water is used, a site for operation is

selected on the shore as remote as possible from streams, so as to obtain the most highly saturated water. When salt springs are used as a source, an increased flow is secured by sinking wells to the subterranean stream. When rock-salt deposits are located beneath the surface of the earth, they are frequently mined by sinking wells through which to admit fresh water, which, after being saturated, so as to form brine, rises, or is pumped, to the surface again. In many instances these deposits are mined, as other mineral deposits are, by sinking shafts, driving galleries, and blasting out or breaking down with explosives." *

The salt industry in America had its beginning very soon after the early settlements of the country. In Virginia there were crude salt works in operation before 1620, and four years later the first attempt to manufacture salt in New England was made at Cape Ann. Much salt was made from boiling sea water during the Revolutionary War period, and afterwards an extensive system of solar evaporation sprang up around Cape Cod. The sea water was pumped by windmills into long lines of vats which were provided with movable roofs and uncovered in dry weather. In 1830 the production by this method was six hundred thousand bushels of salt, about half of which was made in Barnstable County, Massachusetts. By 1834 a reduction in the tariff, and the cheap supplies of foreign salt, and that from the rich brines of Onondaga County, New York, rendered manufacture in Massachusetts unprofitable. In Cape May County, New Jersey, brine was formed by allowing the sea water to flow into large holes in the sand of flats; and, when it had become concentrated by natural evaporation, a barrel of it boiled in kettles yielded a bushel of salt. The industry was started in Florida in 1840, and in California about 1848, along San Francisco Bay. From 1810 to 1870 as many as twenty-six States and Territories had been reported as producers of salt.

In the inland States the sources of supply is salines or

* Census of salt manufacture, U. S., No. 83, 1905, 76.

the brines from rock salt deposits. As early as 1720 the French operated salt vats, the supply being obtained from the former source near Equality, Illinois; and in 1784 salt works were put up on Big Beaver Creek, in Pennsylvania. In 1791 salt was made at Avery Island, Louisiana, but not until 1812 was the work successful. Many years after, in 1862, the deposit of rock salt from which the brines originated was discovered, and the salt has since been mined like other minerals. The industry was established in Kentucky in 1795; in Ohio at the old Scioto works in 1798; and in Nebraska, Missouri, Arkansas, Indian Territory, and New Mexico prior to 1860, but salt was produced only in small quantities for local consumption. The production of salt from the incrustations on the shores of Great Salt Lake was begun with the settlement of Utah by the Mormons, in 1847. In 1857 Texas produced twenty thousand bushels of salt from a salt lagoon near the Rio Grande, but the first salt well in the State was not sunk until 1884. The industry in Kansas was of little importance until the discovery of a body of rock salt at Lyons, in 1887. Nevada made salt for the first time in 1880, and Oklahoma in 1896.

In New York the salt springs of Onondaga County were known to the Indians at an early period, and were mentioned by Le Moyne in 1653, although it is possible that they were discovered prior to 1649 by Father Lallemont. A century later salt from these springs was in use among the Delaware Indians, and was sent to Canada for sale. In 1788 a treaty with the Indians provided for the care of the springs by the State, to the benefit of both races; but a few years later the Onondaga salines and the land about them, some ten square miles in area, were ceded absolutely to the State. The consideration was one thousand dollars in cash and annual royalties of seven hundred dollars and one hundred and fifty bushels of salt. The area included the site of the City

* Census of salt mfr., U. S., No. 83, 1905.

of Syracuse and several towns, besides the whole of Onondaga Lake.

Salt-making privileges were leased to private individuals under a levy of four cents a bushel, and the price was restricted to sixty cents a bushel. In 1812 the royalty was raised to twelve and one-half cents per bushel, to aid in canal-construction; but in 1834 it was reduced to six cents, and in 1846 to one cent per bushel, which rate prevails to-day. The wells were driven by the State; the brine was pumped and delivered to the salt-makers; and the State inspected and weighed the salt. In 1797, when the first leases were made, the salt production was 25,474 bushels, and it steadily increased until 1862, when it reached the maximum of 9,053,874 bushels.

At this time the competition of Michigan salt, produced from stronger brines and with cheap fuel, began to be felt. Because of the location of the Michigan wells and salt works, affording cheap transportation by the Great Lakes to the South and West, and owing to the cheap Liverpool salt brought across the Atlantic in ballast for consumption in the East, the market for Onondaga salt became much restricted and the industry declined, so that in 1876 the production fell to 5,392,677 bushels. There was improvement later, however, when chemical works were established to convert the salt at the wells into a more marketable and valuable product.

"While sinking a prospect well for oil in Wyoming County in 1880, a deposit of rock salt 70 feet in thickness was discovered at a depth of 1,300 feet, and other deposits have been found in Genesee and Livingston Counties, and salt works established. The brines from these wells in Western New York contained from 23 to 25 per cent of salt, while the deep wells of Syracuse gave brine carrying only from 17 to 20 per cent, and the shallower wells still less. In practice two tons of fuel would produce as much salt at the works in Western New York as three tons would at Syracuse. This advantage for the western

works was partly offset by that which the Syracuse works derived from their proximity to the Erie Canal, by means of which their product could be more cheaply transported to the seaboard. Since 1885 the deposits of Western New York have been operated at a number of points by the regular methods of mining, thereby yielding rock salt. The amount of rock salt produced in New York in 1900 was 1,866,550 barrels (five bushels), and in 1905 it was 2,141,371 barrels, an increase of 14.7 per cent.

"The salt springs of Michigan were likewise known and used by the Indians. On March 4, 1838, over a year after Michigan became a State, an act was passed directing the State geologist to bore for salt at one or more of the salt springs, and appropriating $3,000 for the purpose. The result was not satisfactory, nor were the subsequent official tests, made in 1840–41–42. In 1859, encouraged by a bounty of 10 cents per bushel, offered by the legislature for all salt made in the State, a private company sank a well at East Saginaw, and obtained at a depth of 669 feet, nearly saturated brine. The industry thus established grew to the first magnitude." *

Salt was obtained at an early date in Kansas, usually from the salt marshes in the central part of the State, but the business was not organized on a commercial scale until 1867. The first well was driven at Solomon City; but the industry assumed importance only with the discovery of a body of rock salt at Lyons, Rice County, in 1887. Since then no State has made such rapid progress in salt-production. There is a vein of rock salt from three hundred to five hundred feet in thickness, running from north to south, at a depth of from four hundred to eight hundred feet, and about fifty miles wide. This has been tapped at a number of places. Hutchinson now claims the largest salt works in the world, and Anthony claims the purest product. Salt was discovered at Hutchinson during the great Kansas boom of the later eighties, by a man named Ben Blanchard. He saw the possibilities of the business and went East to get money. Starting

* Census of salt manufacture, U. S., No. 83, 1905, 78.

back toward the West from Terre Haute, Indiana, with a full train of Pullman sleepers well filled with capitalists, he met obstacles almost at the beginning of prospects of success. He had not a dollar to his name, and no credit, and when the train reached Chicago the healthy bluff he had worked faded away. The railroads wanted something more substantial than mere promises, and refused to haul the train farther, without payment of all transportation charges. But he was undaunted by this discouraging setback. Under pretence of showing the wonders of the stockyards, near which the train had been sidetracked, he kept the crowd interested while he was busy among the bankers of the city in the endeavor to raise the necessary funds. With characteristic nerve and energy he succeeded; he finally landed his moneyed men in Hutchinson, and actually got them enthusiastic in his scheme. The rock salt mined in Kansas in 1900 was reported as 468,029 barrels, and that of 1905 as 991,878 barrels, an increase of one hundred and eleven and nine-tenths per cent.

The production by States, with number of works, quantity in barrels for the years 1890 and 1900, and the wage-earners and value for 1905, compiled from the last report of the census of manufactures, is shown in the following table:

STATES	1890		1900		1905			
	Works	Barrels	Works	Barrels	Works	Barrels	Value [1]	Men
Michigan	81	3,729,110	53	5,206,510	41	4,345,213	$2,404,717	1,388
New York	50	3,226,250	38	4,894,852	34	5,494,869	3,167,279	1,373
Ohio	9	409,514	10	1,460,516	8	1,538,930	1,167,540	539
Kansas	23	1,140,799	8	1,645,350	10	2,148,152	1,123,114	526
California	9	255,328	24	640,420	26	939,800	428,632	313
West Virginia	5	285,461	4	221,534	3	130,360	115,732	80
Oklahoma			4	4,856	3	11,428	5,498	10
Nevada	3	25,250	3	7,671	3	26,285	30,000	14
Texas	2	(2)	3	312,436	7	450,027	351,050	172
Utah	9	626,429	5	235,671	5	1,088,374	236,997	68
All other States	9	708,719	7	558,003	6	980,171	407,097	183
United States	200	10,406,860	159,15	187,819	146	17,153,615	$9,437,662	4,666

[1] Includes packages.
[2] Included in "other States."

In 1906 the total production of salt in the United States was 18,598,700 barrels, valued at $6,179,666 (exclusive of packages), of which five States, Michigan, New York, Ohio, Kansas, and Louisiana contributed 90.62 per cent. The States of Michigan and New York alone manufactured more than two-thirds or 67.14 per cent of the total amount produced. Michigan leads in quantity, when the brines used in the great chemical works in the State are included, but New York leads in point of valuation. It is the chemical works in Detroit, Bay City, and Midland which have brought about the greatest advance in the industry in Michigan, the sodium bromide and other products being extracted direct from the brine without first concentrating into salt. But in determining the production of salt in this State the quantity of salt which would have been derived from the brine used in making the chemicals is very properly included.

The manufacture of salt alone is productive of very small profits, but the making of by-products by new and economical processes is gradually bringing about a revolution in the business. The cost of fuel is the largest single item of expense of manufacture, and the effect of the loss of a local supply of wood is especially noticeable in Southern Ohio and some parts of Michigan. Without the once cheap wood from neighboring forests it does not pay to operate the wells, and hundreds of pumps that in the early days were active are now in disuse, and the salt blocks are in ruins. In the ten States in which salt is produced on a commercial scale, the great question, aside from that of the cost of manufacture, has usually been the sale of the product, so that the distribution might entail the minimum freight haul. In this respect Michigan has the advantage of cheap water transportation, by which its salt reaches the large markets of the Middle West. In this State the salt industry was developed with its early history because the lumber business and salt-making went hand in hand. In connection with many of the sawmills

wells were sunk, and the refuse and scraps from the saws were used for fuel to operate the brine pumps, while the exhaust steam from the main engines was used in heating the brine for evaporation. With the depletion of the forests this waste fuel no longer exists, and as a result, many of the old productive wells have been plugged and the salt blocks dismantled.

"The economical application and utilization of heat is the basis of the salt industry, and the value of any given process depends upon its efficiency in this respect, while the cost of fuel required to make a bushel of salt from the brine of a district is the determining factor in considering the ability of the region to hold its own in business competition. We shall be aided in the discussion of this question if, before examining the various processes in use, we compare from this point of view the brines of a few typical localities.

"In the following table the average salt contents is given, the amount of coal required being taken from Englehardt's table:

	Per cent salt in brine	Pounds coal for one bushel
Warsaw, New York	25	28
Syracuse, New York	18.5	41
Saginaw, Michigan	17.5	44
Pomeroy, Ohio	7.5	112

The concentrated brine of Warsaw, therefore, requires the least coal, the Pomeroy brine the most; but the cost of fuel at Syracuse is greater than at Warsaw and much greater than at Pomeroy, where the salt works are located at the entrances of the coal mines and burn the unmerchantable slack and top coal; while at Saginaw, consuming the offal of the lumber mills utilizes a material otherwise worse than useless. For this reason the competition of Saginaw overshadows all other regions. The sawdust and offal produced by the great lumber industries, though utilized as far as possible for other purposes, remain in enormous quantities, and if not burned must be removed at considerable expense. Hence, it is a positive economy to manufacture salt even though the price obtained for the product barely cover the cost of manufacture. The salt industry is, therefore, here closely connected

with the lumber interest, the exhaust steam from the mills being utilized in the grainers, which are heated by direct steam when the mills are not running, while the pan blocks are also fired with the offal. . . . The Salt Association of Michigan, managed with great skill and energy, is constantly extending its field of operation; and while the introduction of its product into new markets may, for a time, be attended with no profit and even perhaps, by a slight loss, yet the general result is satisfactory to those concerned.

"The position of Syracuse in relation to the strength of its brine and the cost of fuel is less satisfactory than that of any of the other districts, and the results of outside competition and consequent low prices realized are shown by the long lines of idle salt blocks, with their tall chimneys standing as monuments of a departing industry." *

The methods of obtaining salt and refining it for the various purposes of trade vary greatly with the nature of the deposits. The two original sources, namely, surface incrustations or concentrated sea water, and rock salt deposits of a prehistoric age far down in the earth's crust, are still drawn upon for the world's supply. But the processes employed in recovering the saline product from surface deposits are simple, and require but little machinery at small outlay, compared with the more or less complex processes of mining rock salt or of purifying the brines and refining the precipitates. The comparative ease with which the former salt deposits are worked, and often the advantage of being remote from other supplies, entailing high freights, usually render such operations of great economic value. The Pacific Coast, and regions accessible to the Great Salt Lake and the Salton Sea, are particularly favored by nature in this respect.

At Saltair, near Salt Lake City, Utah, and at San Pedro, the seaport of Los Angeles, California, extensive salt-

* Chatard, U. S. Geol. Sur., 1885-86, 504-505.

making operations from deposits of this kind are carried on. The processes employed at these places are very much alike. In recovering the saline product from sea water, because of undesirable impurities also held in solution, the water is passed through a series of settling ponds, before evaporation sets in. At Saltair these ponds are on the shore of a lake, and the water is pumped in, but at San Pedro, they are at the lowest level and are flooded at high tide, the flow being controlled by tide gates. Adjoining the first of these, or "stock" ponds, are grouped the shallower harvesting ponds, each about one thousand feet long and eight hundred feet wide. The operations at Saltair begin about May 1, when the stock pond is pumped full of water from the lake and allowed to stand until most of the impurities have been precipitated. The water is then drawn off into smaller ponds to a depth of about six inches, and the supply in the stock pond replenished. During the hot season evaporation is about two inches per day, and this loss is made up from the stock pond. One of the principal impurities in the brine, sodium sulphate, rises to the surface and is driven by the almost constant winds to the leeward sides of the ponds. The product here obtained, being impure, is used for cattle and silver-mill; while the nearly pure salt from other parts of the ponds is refined for commercial use.

The ponds are kept well filled with brine during the hot summer months, and on or about the first of September the pumping is stopped. The brine soon evaporates, but the last inch containing the impurities is drawn off to waste. There remain great fields of glistening white salt, most of which is in the form of large crystals. The deposits are from three to six inches in thickness according to the weather conditions of the season. The crust is packed hard and must be broken up with ploughs, when it is heaped up in large piles to pass through Nature's process of aeration. In this weathering of the salt, the

climate takes a hand by dissolving various deliquescent salts, which run out in a stream from the heaps, and rain has a further effect in purifying the product.

To refine the salt for domestic and other uses it is carried in standard-size cars over the Saltair Railway to the mill of the Inland Crystal Salt Company. This plant, which is near the salt fields, is constructed in two duplicate sections, each with dryer, six sets of rolls, fans, shaking-sieves, and bagging-machines. The process throughout is very simple, the drying, rolling, and sifting being done by machinery of ordinary type used in other trades. At San Pedro the crude salt is washed in fresh water and raised to a temperature of 360 degrees Fahrenheit. In this high temperature the impurities are volatilized off. It is then ground, sifted, and packed in fourteen different grades of commerce, from the fine powder of the confectioners to the coarse "packer's" salt. The salts of magnesium and the bromides are also recovered to meet the demand of a lucrative market, thus becoming a source of large income and a further economic measure.

Although the mining of rock salt by shafts and galleries has been carried on for centuries in Europe, this method has been employed in America only within the last thirty or forty years, and only in Louisiana, New York, Kansas, and quite recently in Michigan. A single thick deposit of great purity throughout exists in Louisiana, samples of which, taken at random, showed from ninety-eight to ninety-nine and six-tenths per cent of salt. The method of treatment is described in the following words: *

"The mines are operated by the chamber and pillar system, and the salt is excavated by undercutting. When the shaft has reached a depth of, say, 250 feet, or below the apex of the

* Transactions American Institute Mining Engineers, Lucas, 1900, Vol. 29, 462–474.

deposit, stations are opened, and an undercut 7 feet high, with a face of 75 feet, is commenced. When this has advanced, say, 200 or 300 feet, the roof is attacked and blasted down to the height of about 20 feet. After the removal of the salt thus won, there remains a chamber, say, 75 feet wide and 200 feet long and 20 feet high, in which the roof is again broken down to the final height of 70 feet in the centre and 60 feet at the pillars on either side, leaving a natural arch of rock salt, which has proved capable of resisting any overlying weight, as well as preventing leakage of surface waters.

"This final excavation is performed with the aid of tripods, made of short ladders, upon which a temporary scaffold is erected for men and machines. A battery of holes, 10 feet deep, is drilled near the brow of the chamber and along its whole face, and charged with low explosives. The ladders and machines are then removed, and the salt is blasted down. On the pile of this material new scaffolding is erected, and the operation of drilling and blasting is repeated until the desired height of roof is reached. Loose blocks or chips are carefully removed from the final roof, so as to leave a safely solid mass; and the chamber is then abandoned. Every such chamber, 200 feet long by 75 feet wide and 65 feet in average height, yields about 50,000 tons of salt, mined without the use of a single stick of timbering.

"Pillars 60 feet square are left between chambers. Whenever a given level shall have been worked out on this plan, it will be necessary to sink the shaft another hundred feet and repeat the operations described.

"The first undercut of salt is well shattered by blasting, and goes to the mill to be ground fine; the first and second roof blastings furnish pieces of solid rock, which is set aside under sheds to be aerated or weathered before being shipped for cattle purposes. All fine stuff is "grist" and as, by reason of the uniform purity of the salt, no sorting or purification is required, every pound of salt mined is a pound sold. . . . The product is ground, screened and blowed to render it suitable for the various branches of trade."

When the rock salt is mined in an impure state it is dissolved in fresh water and the brine thus formed is treated like the brines from wells and springs, the various processes of which are herein described.

Michigan is the largest producer of salt of all the States in the Union; and wherever there is much exhaust steam available from manufactories in the rock salt districts of the State, the saline product of the earth may be evaporated at a small profit, despite the depleted wood supplies. This is shown in a marked degree in the enormous output of the great salt works along the Detroit River and the St. Clair River, and on the west coast of the State. In the former works coal is the only fuel available, but at Manistee and some minor points in the western part of the State, the lumber industry still in full sway furnishes the wood refuse for fuel.

The supply of brines in the lower half of the lower peninsula of Michigan is inexhaustible, as the entire region is underlaid with a stratum of rock salt, averaging in thickness about three hundred feet, and varying in depth from six hundred to one thousand two hundred feet. This bed of rock salt is saturated with brine to the extent of seventeen to twenty per cent, and it is supposed that a large area of rock salt outcrops in the bottom of Lake Huron, thus providing, by a process of rapid seep, an unlimited supply for hundreds of salt wells of thousands of tons of brine pumped out daily. The Saginaw district has long been the centre of the salt industry of the Middle West, and it is here that the most complete salt-making plant was completed and put in operation in 1906. Advantage has been taken of all new devices, machinery, and methods of handling the product, so that one thousand barrels of fine salt, mined, purified, crystallized, and packed ready for domestic use, without the touch of hand or lift of arm, are produced every twenty-four hours.

The saltworks are adjuncts of one of the large plate-glass manufactories in the West, and the cost of producing fine merchantable salt has been reduced to a figure astonishing to all salt experts. The three factors that bring about this economy are: solid reinforced concrete used in

construction throughout the works; waste exhaust steam from the glass plant; and automatic machinery, by which no hand touches a crystal of salt. Only the master salt-maker and a few helpers are required to watch the machinery, and keep it in perfect running order.

The salt brine is brought to the surface through seven wells, placed from one hundred and fifty to two hundred yards apart, which are about seven hundred and seventy-nine feet deep, penetrating the bed of rock salt for some distance. They are encased with heavy tubing, and in the centre runs a one-inch pipe driven down into the rock. Through this pipe is forced under great pressure a jet of pure water, which at the bottom becomes saturated with the saline element, and is forced back to the surface through the tubing by the continual pressure of the downward rush of water. The drill houses with their high towers, as the structures over the wells are called, enclose the pumping-machinery, which is operated by seven and one-half-horse-power electric motors, the current being furnished by generators in the power plant of the plate-glass works. From the drill houses the brine is pumped to an elevated circular tank of two hundred barrels' capacity.

All brine is more or less impregnated with iron and other impurities; and to free it of these it is drawn from the elevated receiving-tank to a filter, which is sixteen feet square and twenty feet high, placed on top of and at one end of the six settling-tanks. The filter consists of a series of open trays, set one above another about a foot apart, on which are placed scraps of metal of various shapes and sizes. The brine overflows the supply pipe at the top, percolates through the mass of filtering material into wooden troughs below, being aerated and to a certain extent purified in the process. It then flows by gravity into one of the settling-tanks. These tanks are built of solid concrete, each one hundred and seventy feet long by twenty feet wide and seven and one-half feet

deep, and are reinforced by long corrugated rods of iron. Every alternate dividing wall is provided with a narrow plank walk so that the salt-makers can more readily examine the brine. The flow of brine through the troughs along the top and end of the settling-tanks is controlled by a simple arrangement of gates through which it flows into any of the tanks desired.

In these settling-tanks the brine is treated to a solution of lime, which precipitates the remaining impurities, leaving the brine as blue as an ocean expanse, and as pure and clear to the eye, but far more salty to the taste. The purifying of the crude brine through the agencies of the sun, air, and chemical action, having been fully accomplished, the clear brine is ready for the next important operation, its conversion into crystalline form, which is the most interesting part of salt-making. The clear brine is pumped into the salt block, a wooden building one hundred and eighty feet square, and conveyed to two concrete pre-heaters, where it is heated by steam coils and prepared for the grainers.

These grainers, ten in number, are the principal feature of the whole works, and are the only ones ever constructed of solid concrete; by which departure from the old method of using wooden planks, calked, the builders have achieved a remarkable advance in salt-making, the secret of which will soon be shown. The grainers are long shallow tanks of solid concrete, each one hundred and fifty feet long, twelve feet wide, and twenty inches deep. The sides and bottom vary in thickness from six to ten inches. They are built upon a firm earth foundation, and so constructed with expanded steel reinforcement, that no damage can occur by reason of the constant expansion and contraction going on through the changing temperature of the mass. Through the entire length of each grainer are ten four-inch steam pipes, running through truss bars suspended about eight inches from the floor of the grainer, by means of wire cables secured to heavy beams above.

UNIV. OF CALIFORNIA

CONCRETE SETTLING TANKS AND FILTER, SHOWING AERATED BRINE FLOWING INTO TANK FROM TROUGH: DRILL HOUSE IN CENTRE BACKGROUND

ONE OF THE TEN "GRAINERS." THE STEAM PIPES ARE FULL OF LIVE HOT STEAM AND WHEN BRINE COVERS THEM, THE EVAPORATION PROCEEDS RAPIDLY

THE BACK OF SALT BLOCK, SHOWING THE HEAPS OF SALT BEING RACKED OVER THE ENDS OF THE INCLINED SPILLWAY

STORAGE HOUSE HOLDING 45,000 BARRELS, ABOUT 5,000 BARRELS IN RANGE OF CAMERA

All the engines in the large plate-glass works exhaust into an elevated main, twenty-two inches in diameter, connecting the works with the salt block. This main is protected with asbestos covering and the steam is conserved far beyond all the requirements of the salt-making processes. The main enters the block at the rear end, and extends across the ends of the grainers and at right angles to them. At intervals of fifteen feet along the main, smaller feed-pipes run up and over the passageway and downward on the right through the floor and are connected to the steam pipes in the grainers. This is done in such a way that there is equal distribution of steam to all, so that all the ten grainers may be operated at the same time.

When the brine in the pre-heaters has reached the requisite temperature, it is allowed to flow into a grainer, nearly filling it. Exhaust steam is then turned on, and, passing through the steam pipes in the grainer, continues the heating of the brine until a degree almost to the boiling point is reached, when crystallization begins. This is a most interesting chemical action. As we watch the steaming-hot surface of the brine, a pellicle of salt forms; it soon breaks and sinks down, to be followed by another, and then the crystallization proceeds rapidly. It is the extreme rapidity of the process in the concrete grainers that has astonished the old salt-makers, who declare they have never seen anything like it before.

"The secret is this," explained one of them: "the concrete becomes so extremely hot from the maintained temperature of the brine, that it acts as an oven, and actually makes salt on its sides. Why, even after the steam has been turned off, the grainer goes on making salt for an hour or two. We have had to put on scrapers to remove the salt from the sides of the grainers. It is a device of my own which saves the wages of three or four men."

In this saltworks anything that saves manual labor or in any way tends to reduce the cost of making salt is at

once adopted by the company. It is a fact that the estimated capacity of each grainer, one hundred barrels every twenty-four hours, is being exceeded, and frequently one hundred and thirty barrels, or six hundred and fifty bushels, are made in that time.

The salt accumulates rapidly on the floor of the grainer, and to remove it there have been installed the Wilcox automatic submerged rakes, which are placed beneath the steam pipes. These are long rigid frames of steel, running the entire length of the grainer, of angle-iron construction, which slide backward and forward along a steel guideway which is bolted in the concrete walls about six inches from the bottom. At intervals of eight feet, beginning at the extreme back end of the grainer, are hung crosswise rakes of galvanized bar iron, about six inches wide, hinged to turn upward and forward. This steel frame with the rakes is attached at the front end to a hydraulic ram, of nine feet stroke, so that with each forward movement of the ram, the salt is gathered by the rakes and moved along the floor of the grainer nine feet toward the front end. The return stroke places the rake next in front one foot behind the little pile of salt, twelve feet long or the width of the grainer, the hinged rake slipping over, and the operation is resumed. This goes on continually through the whole length of the grainer, a complete stroke requiring about three minutes. The last rake of the series at the front end brings up the accumulated salt on an inclined table which drains off the brine, and then dumps it over the edge into a wooden conveyor below.

As the salt drops into the conveyors, which are twelve inches wide and twenty inches deep, automatic rakes carry it along to a series of hoppers set in the bottom of the conveyor, at intervals of twenty-five feet. Beneath the hoppers are fast-running rubber belts, fifteen inches wide, which catch up every particle of the salt and carry it into the storage building adjoining. The salt, as it enters on

the belt, is caught up by vertical conveyors, lifted to the roof and deposited on other belts which carry it to any part of the big building desired, where it slips off, forming huge hillsides. The power to drive these belts is furnished by a number of electric motors placed at convenient places for the transmission.

The twelve hydraulic rams are actuated by a large three-cylinder pump driven by a twenty-horse-power electric motor, connected direct. It can be operated at various speeds, but the usual pressure to the rams is sixty-eight to seventy pounds. All the steam pipes, rakes, and metal parts in the grainers and conveyors exposed to the brine or salt are heavily galvanized to prevent corrosion or rust, as even a particle of it will ruin a large quantity of the refined salt, or at least render it of use only for cattle and fertilizing purposes.

When the salt has passed the State inspection it is branded with the State and Company brands, and is ready for shipment. If loaded in bulk in cars the operation is simply to run a pair of bucket conveyors into the car, and in a short time thirty tons or more of the glistening white substance have been transferred from the hillsides of salt. The usual practice, however, is to ship in barrels, even though the package costs more than the salt it contains. The filling is done by automatic machinery, by which the barrels are conveyed on a narrow moving platform under the bucket-conveyors, which deposit the product to the required weight, 280 pounds, and are then moved along to a heading-machine, which sets the barrel top and stamps the brand thereon. The barrels are carried forward on the moving platform to the car door, and rolled and stacked in place by laborers.

A further economic advantage to the plate-glass company in the manufacture of salt lies in the fact that two of the constituents of plate glass — saltcake and soda ash — are by-products of saline brines. Besides this advantage there is also the utilization of the waste-heat

energy of large quantities of exhaust steam incident to the making of plate glass. As the brine flows in inexhaustible supply deep down in the earth's crust and under the immense plant, it is, of course, simply a matter of business expediency to bring the brine to the surface and work it up into the various products, some of which are essential to their other processes. The waste bittern water, which remains after the salt has been taken from the brine, is here treated by chemical processes and converted into a dry powder — calcium chloride — which resembles salt. The chemical is used for a variety of purposes, and is in demand principally for refrigerator uses, cold storage, cooling, the making of artificial ice, and to take the moisture out of blast-furnace gases. It is also used on roads to settle dust, as it is cleaner and better than oil. About thirty tons of the substance are made per day in the chemical plant, adjoining the salt block, which is thoroughly equipped for the purpose. In each department of the great industry nothing is wasted.

The solar salt process as applied to brines from rock salt was largely used in the Saginaw Valley in the early days of the industry, but in 1910 only one plant of this kind in Michigan remained. Solar salt, however, commands a higher price than that made by artificial-heat evaporation, because the crystals, being formed more slowly, are larger and harder and dissolve less rapidly. It is especially preferred for "heading" and "layer" in packing meat and fish. The brine is obtained by pumping direct from the rock salt bed and is run into shallow wooden vats or "covers," so called because they are fitted with light movable roofs to protect the brine during a rainfall. Broad aprons, fifteen to twenty feet wide and three inches deep convey the brine from the wells to the covers in a slowly flowing stream about one inch deep. By complete exposure to the sun's rays and winds its evaporation and purification are greatly facilitated, so that when it reaches the covers the salt crystal-

lizes out readily in a saturated condition. A cover is sixteen by eighteen feet in size, and from seventy to eighty bushels, and at times as high as ninety-two bushels of salt are obtained from each. Without aprons, the yield is only about fifty bushels per cover.

The Ohio salt-fields are situated at Pomeroy, on the Ohio River, about midway between Pittsburg and Cincinnati. At this point the salt-foot lies about fourteen hundred feet beneath the surface, and is formed by the ending of the trough-like basins or beds of salt sand which lie between strata of shale, which are impervious to water. Some hundred miles toward the northwest the strata come to the surface, and through the extended opening rain water enters and slowly seeps through the salt sand in the basin, taking up the saline element as it goes, until it reaches the foot in a vast salt lake under Pomeroy. This bed or deposit is about ten miles long and five miles wide. The salt industry was here started at the close of the Civil War, when there was great demand for the product throughout the South. A few years later there were as many as twenty-seven saltworks in operation, and the price of the salt was so high that for a time every dollar invested returned one dollar and sixty-eight cents as annual profit. In ten years the production had increased to such an extent that the price dropped to a figure which brought about normal conditions in the industry. There are now eight saltworks in operation in the district. The brine, however, as has been shown, is weak compared with that obtained from rock salt, and it would not be possible to make salt here at a profit were it not for the cheap coals mined in the immediate vicinity. The distance of this locality from other sources of supply, and the cheap transportation by the Ohio River, which opens up markets to the South and the West, together with the by-products, render the salt-manufacture profitable.

Because of the weakness of the brine it must have a

treatment somewhat different from that of the Michigan and New York brines. Of the operation of the White Rock furnaces, an authority says:

"The principle of the method is the boiling of the brine in a steam chest, by which a portion of the impurities is rendered insoluble, and a large supply of low-pressure steam is obtained, that is utilized in the further evaporation of the brine. Owing to the large amount of the very soluble 'mother liquor salts,' fractional crystallization must be resorted to; for, if the brine at different stages of the process be evaporated beyond certain points, the resulting product will be too impure. Hence the grainers are arranged at different levels, so that the mother liquors can be drawn from one to the other, giving a series of products of which the early ones are ready for market, the later being redissolved in the settlers. In this way the process is practically a continuous one, the concentrating brine passing from one to the other of the settlers and grainers in regulated succession, depositing, in its passage, salt of various grades, and the mother liquor loaded with impurities, going to the bromine works, where that valuable constituent is extracted and the residue itself made into a marketable product.

"In this instructive process the aim is to have nothing but condensed water and ashes as waste; since were it not for the by-products, many of the works would be forced to suspend operations, owing to the low price to which salt has been forced through domestic competition." *

If the salt brine in the grainers be left undisturbed it will not crystallize properly. When the solution evaporates slowly, the salt crystallizes out in cubes, which coalesce into the form of hoppers; and when it evaporates rapidly the crystals are smaller but form a thin crust over the brine, and this retards the evaporation of the brine beneath. To overcome this, the salt-maker, at a certain stage of the process, throws lumps of tallow here and there over the surface of the steaming-hot brine, thus

* Chatard, Seventh Annual Report, U. S. Geol. Sur., 1885–86, 552–556.

forming a thin film. This is followed by an application of rancid butter which, spreading out over the surface, causes the crystals as they form to settle to the bottom of the grainer, leaving the brine clear. These applications are made from time to time during the twenty-four hours of continuous operation. Strange as it may seem, none of the properties of the grease follow the salt, but pass off with the salt bittern. In the Saginaw Valley works, the self-rakers, by keeping the solution constantly stirred, render such applications of grease unnecessary.

Salt, as one of the common products of the earth, proves, by man's need of it as a food and as a food preservative, and also by its various uses in the mechanic arts, its economic value to mankind. Its manufacture, particularly in the modern concrete works, is one of the most cleanly of the food manufactures, and the salt-makers are careful in this respect. It is, however, perhaps little known that the refined table salt, as used in nearly every article of food, contains elements of poisonous nature. Enough salt is used to season a bowl of soup to kill a person if the elements of which it is composed were taken separately. These chemical elements are metallic sodium and chlorine, which, though poisonous of themselves, are not only entirely harmless when combined in the salt, but are conceded to be conducive to good health.

The amount of salt used in different foods depends very largely upon the nature of the articles, and whether it is used alone or in combination with other preservatives. The demands of taste vary also and, where a number of years ago one ounce of salt added to every pound of fresh butter, now, only one-half ounce or even less is used for seasoning the same quantity. In making bread the use of salt not only removes the insipid taste, but checks the tendency to lactic fermentation which would likely follow the alcoholic fermentation that causes the raising of the dough. The average percentage of salt in all

varieties of salt fish is twelve and five-tenths; in desiccated soup and dried and smoked beef it is nine; in potted meat, six; in meat extract and sausage, five; in bacon, butter, corned beef, and ham, four; in bread two and a half, and in concentrated soup it is two.

The quantity of salt consumed for specific purposes, 1905, is shown in the following table, Census of Manufactures, 83.82.

	Total consumption (domestic)	Quantity (barrels)
Soda products and bleaching materials	4,876,387	
Chemicals	1,069,171	
Curing and tanning hides and skins	446,542	
Freezing-mixtures	412,825	
Muriatic acid	343,029	
Soap	324,486	
Chlorination	150,000	
Pottery, terra cotta, and fire-clay products	59,300	
Dyestuffs and extracts	20,464	
Fertilizers	17,186	
Brick and tile	16,771	
		7,736,161
Food, preservation of food, and all other uses		15,368,538
Total		23,104,699

In chlorination, salt is used for the recovery of precious metals from their ores, and in tiles and pottery in the process of salt glazing. It is also used in top-dressing soil for eradicating weeds; in artificial mineral waters; for surgical purposes; and many minor uses.

III

SUGAR

THE SCIENCE OF SUGAR MAKING

GREAT DEMAND FOR SUGAR IN THE UNITED STATES — ECONOMIC SOURCES OF THE SUPPLY — THE WORLD'S PRODUCTION AND CONSUMPTION — ORIGIN OF THE MANUFACTURE OF BEET SUGAR — MANUFACTURE OF CANE SUGAR AND MOLASSES — BEET SUGAR INDUSTRY — EXTRACTING THE BEET'S SWEET CRYSTALS — THE PROCESS OF BOILING — ABSORPTION OF IMPURITIES BY LIME AND GAS — SEPARATING THE CRYSTALS FROM THE SYRUP BY CENTRIFUGALS — THE GRANULATING PROCESS — THE PACKING-ROOM — BEET-CULTURE VERY PROFITABLE TO FARMERS — FOOD VALUE OF SUGAR AND SYRUP — MAKING MAPLE SUGAR AND SYRUP.

IT costs something to cultivate the sweet-tooth; at least the people of the United States have found it so. They use on the average their own weight of sugar every year, at a cost of something like four hundred and twenty-five million dollars; and they are not content with being the greatest sugar-eaters on earth, but are continually demanding more. Although the average price in the year is, perhaps, one and one-half to two cents higher than it ought to be to return merely a reasonable profit to the cane and beet growers and the refiners, the consumption of sugar and syrup has more than doubled in the last seventeen years. In 1909 it reached an average of eighty-three pounds for every man, woman, and child, not taking into account the vast quantities of syrup, honey, and other sweets. Whether the so-called Sugar Trust, by its alleged manipulation of sugar stocks and the consequent stifling of competition, or the increasing amount of saccharine matter which is needed to satisfy the cravings

of ninety-odd millions of people, is responsible for inflated prices is generally determined by one's view of the trust question. The problem is of very live interest to nearly every American citizen, and when all the contributory causes have been carefully weighed, it will probably be found that these two causes are chiefly to blame. But the people, determined to gratify the sweet-tooth, keep on eating sugar with seemingly greater relish.

Sugar, in some form or other, is in almost universal use in all parts of the world; and although the enlightened races have developed the art of sugar-making to a high degree, the semi-civilized peoples obtain their sweets in the crudest ways. The saccharine element is found, to a greater or less extent, in all fruit and vegetable juices, particularly those of the tropics, but the cost of production is so great as to render it of no commercial value. The economic sources of supply are limited to the cane, beets, corn, and the juice of the maple. Large quantities of corn syrup, or glucose, are made from starch and other corn products; but no process has as yet been devised to reduce it to the form of sugar at a moderate cost. It is fortunate that one or all the sources of the world's supply are agricultural products of every civilized land, and can be grown, and the sweet content extracted therefrom.

The world's production of sugar in 1907 was 32,179,700,000 pounds, which was about equally divided between the cane and the beet, fifty and three-tenths per cent being credited to the cane and forty-nine and seven-tenths per cent to the beet. Of the sugar made from cane Asia, Africa, Oceania, the West Indian Islands, and the Americas with Hawaii and the Philippines, produced by far the bulk of the supply. Beet sugar is made almost exclusively in Europe and the United States, but about ninety per cent of it is produced in the former. Germany is the largest producer of beet sugar in the world, the industry having been introduced there many years ago, and brought to a high development. The Germans are the world's

authorities on beet culture, seed production, and the science of sugar-making and refining.

Of the world's consumption of sugar, the United States used in 1907, twenty-two per cent, or 7,089,700,000 pounds, which was divided in the proportion of about four pounds of cane sugar to one pound of beet sugar. The bulk of the raw sugars from the cane comes from Cuba, Porto Rico, Hawaii, and the Philippines; Louisiana and Texas produce much cane, which is mostly used in making molasses of various grades. Hawaii, which fifty years ago produced hardly enough sugar for home consumption, exported eight hundred and twenty-one million pounds, valued at twenty-four million dollars, in 1906. The Philippines now produce more than three hundred million pounds of sugar annually, and their sugar crop soon will have to be reckoned with. The production of beet sugar in America is of comparatively recent development, the output increasing from four million nine hundred thousand pounds in 1890 to nine hundred sixty-seven million two hundred thousand pounds in 1907.

The source of supply for the enormous consumption in the United States is given for 1890, 1900, and 1907, in the following table:

Produced in U. S.	1890	1900	1907
Cane	305,800,000 lbs.	334,200,000 lbs.	544,300,000 lbs.
Beet	4,900,000 "	163,400,000 "	967,200,000 "
Total	310,700,000 "	497,600,000 "	1,511,500,000 "
Brought from			
Porto Rico	76,900,000 "	72,600,000 "	408,100,000 "
Hawaii	224,500,000 "	504,700,000 "	821,000,000 "
Philippines	259,800,000 "	49,500,000 "	25,200,000 "
Imported from			
Cuba	1,041,100,000 "	705,500,000 "	3,236,500,000 "
All others	731,600,000 "	1,984,300,000 "	732,500,000 "
Beets, all others	601,100,000 "	701,500,000 "	397,700,000 "
Total	2,935,000,000 "	4,018,100,000 "	5,621,000,000 "
Grand total	3,245,700,000 "	4,515,700,000 "	7,132,500,000 "
	1890	1900	1907
Exported	48,500,000 lbs.	26,900,000 lbs.	42,800,000 lbs.
Total consumption in United States	3,197,200,000 lbs.	4,488,800,000 lbs.	7,089,700,000 lbs.

It will be seen that the production of cane sugar in the continental United States has not kept pace with the increasing consumption, while on the other hand the new industry of beet sugar has expanded greatly. Although the imports of beet sugar have fallen off about thirty-five per cent in seventeen years, the domestic production has increased to such an extent that the people use one hundred and twenty-five per cent more, or 1,364,900,000 pounds more than in 1890. The imports of cane sugar from Cuba have more than trebled during the period, and since the annexation of Porto Rico and the establishment of free trade with that island, the quantities of sugar brought from there have increased enormously.

The art and science of sugar-making date back to the first century of the Christian era, when the sweet sap of the Indian reed or sugar cane was sought and reduced to a syrup. But it was those versatile people, the Arabs, who introduced granulated sugar made by processes peculiarly their own. In time the art of refining sugar with ashes was made known to the Egyptians, who in the seventh century transmitted the knowledge to the Chinese. It is known that sugar was made in Persia also at a very early day, and from Arabia the culture of sugar cane and the extraction of its sweet content spread to many lands.

Until 1747, sugar was supposed to be the product of sugar cane only, but in that year, Marggraf, a German chemist, demonstrated that it was a natural product of other vegetables, and especially of the beet-root. It was near the end of the century, however, when its manufacture from that source was begun in Silesia. Almost all the sugar consumed in Europe is now, for economic reasons, obtained from this source. The cultivation of the sugar beet and the care of the soil, in Germany, are objects of national concern; the machinery used in the industry is perfected, and the workmen are highly skilled in the art. It is from them that the people of America

have learned the science, and from them that the beet seeds are imported.

In the United States sugar cane was almost the only source of supply until about 1890, the great refineries in New York, Philadelphia, New Orleans, and San Francisco producing practically all the sugar consumed. The domestic production of cane sugar increased steadily in the South; in 1907 the cane belts of Louisiana and Texas produced four hundred and eighty-six million pounds. On the big plantations cane is grown primarily for the manufacture of sugar, while on the small farms, particularly those of East Texas, it is chiefly used in making syrup.

The making of raw sugars, after the juice is expressed from the cane in grinding and crushing-mills, consists of extracting the impurities — such as mineral substances, acids, and albumen — from the raw juice. This is done by the use of lime and chemicals, and by boiling down the clarified juice in successive pans until it is ready for granulation. It is then allowed to cool in shallow pans, when crystals form; and then the remaining syrup drained off. The unrefined sugar is sold to refineries, or worked up in centrifugal sugar factories. It is melted down, thoroughly filtered, and the syrup passed through beds of charcoal. After boiling in vacuum pans for a time, the liquid is ready to crystallize, and the syrup that remains is driven off by centrifugal or other force. The granulating process, which follows, prepares the sugar for the ordinary uses of commerce.

Syrup, or rather molasses, is one of the by-products of sugar mills, which is left after the sugar is removed, and its grade is determined by the amount of sugar which has been taken from the liquid after boiling down. There are " firsts " and " seconds " : the molasses of everyday use, and the lowest grade, or " blackstrap," which is eaten with great relish by negro farm hands, and also used for feeding stock.

On the farms where the cane is not sold to the sugar

mills, syrup-making time is one of jollification and merry-making. The young folks of the neighborhood congregate at the crude and improvised syrup-factory at night and, while helping in the work, eat sugar cane, drink the raw juice, and enjoy rough and tumble games. The juice of the cane is usually pressed out by means of rollers in a small machine, which is operated by a horse or a patient mule attached to a beam that goes round and round, very much like the power for the hay presses and wood-sawing machines of earlier days. The juice is boiled in pans in the open air until it reaches the desired density, very near the sugaring stage. Great care is taken lest the syrup scorch, or boil over, or sugar, the sugar-maker standing ready to dash raw cane juice into the pan or regulate the heat, at the first indication of mishap.

When the grower has put away all the syrup he needs for home use, the remaining stock is sold to a local merchant or individual customers, although, in some cases he finds it more profitable to sell it in bulk to syrup-blenders, who prepare the products of many farms — syrup of varying color, taste, and density — and mix them to make uniform grades for the wholesale trade. The leading syrup-blending firms in Louisiana sell six or more different grades of syrup or molasses, each being a blend of various syrups in exactly the right proportions to produce an even and uniform quality every month of the year. This is a decided advantage to the consumer, because he knows by the brand just what he is buying. The proportion of each syrup to be used in a blend is determined by an expert chemist, by analysis, the experiments being carried on in a complete laboratory attached to the plant.

The syrups are placed in immense mixing vats with paddles revolving within, and the mass is thoroughly churned and stirred; then it is drawn off through a system of pipes to a large heating-kettle. This brings the

syrup to the proper temperature for filling the cans. It flows through pipes to the canning-room on the floor beneath, where the cans are filled and sealed and shoved along a sort of chute for the label; it is then packed for shipment. At no time in the process has the syrup been exposed to the open air, as it is protected from dust and other impurities by the complete system of piping and pumps.

Centrifugal molasses, a product of the sugar factories and refineries, varies as does the farm syrup, and is often blended by the same process. For some grades glucose, or corn syrup, is added, not as an adulterant as is popularly supposed, but because many people prefer it as a matter of taste to the pure cane syrup. By reason of its rich golden color the corn syrup blends very well with some of the darker cane syrups, and by this blending the keeping quality is improved, especially in hot weather.

The experimental period in the beet-sugar industry in the United States had its beginning as early as 1830, when a small factory for making sugar from beets was built and operated in Philadelphia; and ten years later another factory was built in Connecticut. Both were failures, because of careless methods of beet-culture and the crude system and apparatus used in the factories; and furthermore, neither factory was well situated in a good beet-growing district. The industry was not revived until 1870, when a factory was set up at Alvarado, California. Six years later the company failed, and not until 1879 was it reorganized; but it has been in operation every season since. As late as 1888 the output of this factory was only two million pounds of white sugar a year.

In 1891 the beet-sugar industry had its practical beginning at Chino, California, thirty-three miles east of Los Angeles. Several thousand acres of the waste land in lower Pomona Valley, at that time but recently reclaimed by irrigation, had been planted to the mangel-

wurzel beet. This species of the sugar beet was well adapted to the soil and climate, for the crop was a complete success, the beets growing in many instances to the size of a man's body and extended a foot or more above the ground. The beets contained from ten to twelve per cent of saccharine matter.

Meanwhile, a large factory had been erected, and machinery such as is used in Germany was imported from that country. It was necessary also to bring over mechanics to set up the machinery and afterwards to operate it, so little being known in this country of the details of the machinery and the science of sugar-making from beets. The success of the Chino factory, owned by the Oxnard interests from the very start, led to the planting of tracts of land in California to beets, the erection of factories, so that in a few years the industry became well established on the Pacific Coast.

It was not long before capitalists and farmers in Washington, Oregon, Montana, Utah, Colorado, Nebraska, Minnesota, Kansas, Iowa, Indiana, Ohio, New York, Wisconsin, and Michigan were attracted by the possibilities of the beet-growing and sugar-making industry; and experiments were made toward adapting the various seeds used in Germany to the soils of the different States. The selection of the proper seeds for each soil is a very important matter, and in fact, combined with proper fertilization and intensive cultivation, it is the key to success. Wherever sugar beets can be profitably raised and the factories are properly managed, the industry flourishes: in 1909 there were sixty-seven beet-sugar factories in operation in the United States.

Although these factories produced one billion pounds of granulated sugar in the season's run, this vast quantity, as has been stated, is but one-fifth of the nation's consumption. To supply the entire needs of the country, four hundred factories would be required, and thereafter at least ten new ones added every year to keep up with the

increasing demand. That this expansion of the industry will ever be realized is far from probable, because of the immense quantities of raw cane-sugars imported from our insular possessions; for, those sugars being produced and shipped by cheap water-transportation to the great refineries, it is to the advantage of the Eastern sugar interests to enhance the amount produced. The sugar trust, so called, now controls the beet-sugar manufacture by investment in large blocks of the factory stocks, and it will not allow further expansion of the industry.

The development of sugar-making within the last ten or twelve years in the Middle West is very interesting. The soils of nearly all the States in the agricultural belt extending east and west between the fortieth degree and the forty-fifth degree, north latitude, are especially adapted to beet-growing. They are rich in certain constituents that impart to the white Slesvig beet a high sugar content, the percentage under proper cultivation varying from sixteen to twenty, with an average of about eleven tons of beets to the acre.

The States of Colorado, Michigan, and California, in the order named, are the largest growers of sugar beets, and, of course, produce the most beet sugar, a ready market for which is found in the Middle West and the Western States. Not a great quantity of cane sugar reaches the markets west of the Mississippi, for the reason that the long freight haul from the refineries on the Atlantic Coast and the Gulf, renders shipments almost prohibitive in competition with the beet sugar made near at hand. The beet-sugar factories in Colorado, Utah, Idaho, Nebraska, and other Western States east of the Rockies supply that vast territory; while the California factories and refineries, which work up the raw sugars brought from Hawaii and the Philippines, supply the natural and growing demand of the coast country.

In Michigan, which follows Colorado so closely in point of production as to be of equal importance in the

industry, the soil and climate are peculiarly adapted to the growth and culture of sugar beets; and there are sixteen factories in operation during the season's campaign, which generally begins early in October and ends sometime in January. The industry here cuts beets from an acreage exceeding one hundred and twenty thousand, and the crop is worth five million five hundred thousand dollars annually to the farmers of the State. The average test of beets for sugar content, in 1909, was above sixteen per cent, producing more than two hundred and thirty million pounds of granulated sugar. The skilled workmen numbered fifteen hundred, and their average wage was two dollars and ninety-three cents per day, while the common laborers, such as coal and lime passers, and unloaders, to the number of two thousand five hundred were paid an average of one dollar and sixty-eight cents per day. To the communities at large further direct benefit was derived from the large purchases of coal and limestone, and to the railroads for hauling the beets and other materials, and also for hauling the hundreds of carloads of refined sugar to the markets near home and to points in the Middle West.

The Michigan Sugar Company, capitalized at five million dollars, is the largest producer in the field, and operates six large factories situated in the richest beet-district in the country, namely, the Saginaw Valley, the Sugar Bowl of Michigan, once famed as the great lumber mart and producer of the clearest cork-pine ever known to the trade. Where once stood the magnificent giants of the forest, sixty feet clear and straight to the first branches, there now grow succulent beets rich in sugar content. The "sugar bowl" is about fifty miles in diameter, and within it are nine large factories with an aggregate cutting capacity of seven thousand tons of beets per day of twenty-four hours. The season's run, of about one hundred and ten days, amounts to about one hundred and forty million pounds of granulated sugar. The other seven

factories in the State are widely distributed in good beet territory, as from Mt. Clemens, near Detroit, to Menominee, on the other side of Lake Michigan.

Active operations for the annual campaign start in September, when the beets begin to mature and the farmers are busy pulling and topping them. Until about 1907 this work was done entirely by hand, but the difficulty of obtaining labor resulted in the perfecting of a machine, that not only pulls the beets without any breakage, but also removes the tops with far greater precision than can be done by hand; and it also deposits the beets and leaves in separate and distinct piles. The company begins receiving beets at the factory the latter part of the month, and, when fully five thousand tons are on hand, and the small army of mechanics has the machinery in the pink of condition, the factory starts for the season's run. A large supply of beets constantly in reserve, and all machinery in fine working order at the start, are very important factors in the successful management of a sugar plant, for the reason that when operations have once begun there is no stop for an instant, at least for very much of the essential machinery. The work goes on at night and day, and on Sundays and holidays, until the last beet has been worked up into fine white sugar. With these facts and figures a visitor is well equipped to make an intelligent tour of the great works, receiving thereby much practical knowledge of the inner workings of an important industry.

The huge storage sheds, four hundred and fifty feet long and two hundred feet wide, are the first points of interest, and are veritable beehives of workers. Through the wide doorways farmers' wagons are entering to unload, after weighing up at the main entrance; while in the farther section of the sheds railway cars are being shunted into place for a like operation. It would be difficult to count the wagons. Sixty-four may be unloaded at the same time, while the number constantly driving

away empty, and others waiting their turn, seem to be as many more. In the railway section gangs of men are unloading the cars heaped high with the rich product of the soil, as many as twenty of the largest gondolas being placed on the two tracks.

The storage bins are constructed of concrete, and are twenty feet wide and eight feet deep, with a V-shaped bottom the whole sloping gradually to the farther end. On leaving at the factory end of the sheds, the first thing to attract attention is a series of concrete flumes, two feet wide and four deep, rounding away from the middle of each bin, and converging at a main flume of somewhat larger size, leading into the main building. Upon looking down into this flume a stream of muddy water is to be seen rushing along and carrying in its current a continuous mass of beets. The water, which is quite hot, is forced through the flumes from the front end of the sheds by power-pumps; and, in conveying the beets to the factory, the further operation of removing the outer layer of dirt and weeds is easily accomplished.

The main building is a structural steel frame, four hundred and twenty feet long, eighty-five feet wide, and five stories in height, upon which rest the ponderous machinery and numerous tanks used in the various processes. The whole framework of heavy columns and immense girders, like the steel frame of a modern city office-building, and its valuable mechanical outfit, are enclosed within walls of brick and concrete, and pierced by many windows to furnish ample light and ventilation. The construction throughout gives an impression of solidity and permanence.

Before entering the main building there is a short passage through a little one-story addition, in which the main flume widens into a shallow pit which contains the lower end of the " scroll," the conveyor which lifts the beets up into the factory. This scroll is in principle an exact Archimedean screw, with the slight alteration of having

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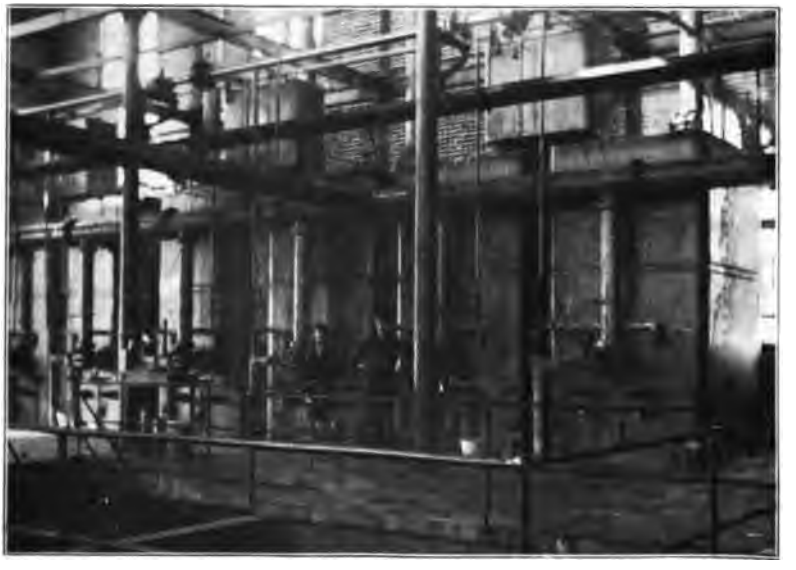
THE "SCROLL" OF ARCHIMEDEAN SCREW THAT LIFTS THE BEETS FROM FLUME INTO FACTORY



THE CARBONATORS, CONCERNED IN THE PROCESS OF PURIFYING THE JUICE

A SERIES OF PRESSURE FILTERS USED TO ELIMINATE THE PURIFYING AGENTS FROM THE JUICE

THE EVAPORATORS: HERE THE PURIFIED JUICE IS REDUCED TO A RICH SYRUP

the lower half of its cylinder perforated with rows of half-inch holes to drain off the dirty water, as the beets are rolled along its revolving blade. A system of levers operates a gate which regulates the flow of beets to the scroll, so that the right amount is supplied at all times to the slicing machine.

Passing along the narrow entry, which is filled with a cloud of steam, and through a doorway, the visitor is at last in the factory of mysterious doings. For a moment he stands spellbound. The massive machinery, the rumbling of hundreds of wheels, the grinding of heavy gears, the hissing of steam as it rushes through the big pipes overhead, are enough to shock the senses of sight and hearing. The next sensation is of stifling heat due to many lines of steam pipes of various sizes, and other pipes full of boiling-hot water; for the principal factor in sugar-making is heat, as utilized through the medium of water in its vaporous state, while as a liquid at different temperatures water is used in many of the processes.

Throwing off outer wraps the visitor is ready to follow the beets, which are coming into the factory at a lively rate. They are forced up and through an opening in the wall and dropped into a washing tank, where they are tossed about in warm water by paddles revolving on a horizontal shaft. In this process the beets are thoroughly scoured and at the end come out on a draining-board, white and clean. From there they are lifted to the ceiling by another scroll, and by a bucket-conveyor are carried to the fifth floor.

The next point of interest is at the topmost platform, under the roof, where the hopper of the huge slicing-machine receives the beets from the bucket-conveyor. From this elevation there is a splendid view through the centre well of the fourth and third floors, of the ponderous machinery and the intense activities of the factory. The floors are constructed wholly of concrete, the stairs and railings are of iron; and throughout there is the

utmost cleanliness and almost perfect ventilation. But despite the attention given to this matter, a pungent odor of lime and sulphur, with a certain acute acidity, is experienced, which at first is not altogether pleasant; but, upon proceeding through the factory, the sights and sounds and smells, as well as personal comfort, are forgotten in the keen interest aroused by each new process.

The huge hopper at the top of the bucket-conveyor, in turn deposits the beets by gravity into a weighing machine which, with every half-ton, discharges the mass through its drop bottom into the hopper of the slicing machine. Every dump is automatically registered so as to determine the exact percentage of sugar obtained from the beet tonnage. As the bottom of this hopper is bell-shaped, the beets are forced outward and fed to the swiftly revolving knives of the slicer. This is a huge upright cylinder within which is a horizontal wheel of the exact inside diameter, and placed slightly below the lower edge of the hopper. The wheel carries on its outer edge or rim an endless line of sharp, corrugated knives about ten inches long, which cut up the beets in a flash as they are pressed down on them by the weight of the mass above. The slicings fall through to a receiver, where they are rasped, to tear up the cells, after which they pass out on an endless belt conveyor on the second floor to be distributed as required to the diffusion-battery in series.

In this process the series of boilers is called a diffusion-battery, because the sugar-content is removed from the slicings by water, into which the sugar diffuses. There are fourteen cells or huge cylindrical tanks, placed upright and close together on the ground floor. Their top openings with the connecting valves extend through to the floor above, so that the steel traps, which are three feet in diameter and open on hinges, may be opened and closed easily, and the valves operated by hand. When three and one-half tons of the beet slicings have been taken into a cell from the belt conveyor, the supply is

shut off or turned by a system of gates to another cell, and the cover or trap is swung back in place and clamped down securely, becoming air tight.

The process of boiling is, of course, unseen, but it is easily understood. The juice passes by a complicated system of pipes and valves through the charged cells of the series, always from the longest-filled cell, which contains nearly exhausted slicings, to the ones most recently filled, thus extracting the largest possible quantity of sugar with the smallest amount of water, which varies in temperature from one hundred and four degrees to one hundred and eighty-five degrees Fahrenheit. All the water, of course, must be evaporated in subsequent processes, and the nearer to saturation this solution becomes in getting all the saccharine matter from the slicings, the greater the economy of operation. In about an hour the slicings have become exhausted of their sweet content, when the door at the bottom of the cell is thrown open by levers, and the mass of beet pulp gushes out and runs off in a concrete flume to the pulp drier. There the pulp is thoroughly dried and compressed into convenient form for shipment. It is extensively used as a stock food as it contains valuable fattening qualities, and also as a fertilizer. The empty cell is then cleaned by jets of hot water which remove any clinging shreds of pulp; and the cell is ready for another charge of fresh slicings. With fourteen of these cells, each one of which is recharged every hour, the process may be said to be continuous.

When the diffusion-juice leaves the battery it is pumped to a receiving-tank and from there to a measuring-tank, which records the amount of juice being obtained from the slicings. In its present raw state it is heavily charged with various impurities, and in order to remove these there is a complicated system of purifying agents. First, the juice is pumped to two superheaters, which are tanks containing vapor coils, and in these the juice is heated to prepare it for carbonation.

In this process the two factors are lime and a gas containing about thirty per cent of carbonic acid. This gas is made by burning lime and coke in the proportion of one part of coke to four or five parts of lime. The kiln is outside the main factory; about thirty tons of lime is made and used every twenty-four hours. The lime is thoroughly slacked with water, and the solution is pumped into the sugar-house, where it is heated in a circular tank to a degree necessary for its useful purpose. The diffusion-juice, already hot, is passed to the carbonators, in which it and milk of lime are thoroughly mixed in the proportion of five quarts of lime to every thousand gallons of the juice, and the temperature is quickly raised to ninety degrees Centigrade. Quicklime is then added — about fifteen pounds to every hundred gallons, and the gas is pumped in by powerful pumps.

The impurities in the juice having been fully absorbed by the lime and gas, it is necessary to remove all traces of these agents; and, since the quality of sugar produced depends on the process of clarification, considerable skill and care are here required. A powerful pump now forces the solution through pressure filters. Each of these is a series of steel frames about four feet square and one inch and a half thick, over which are stretched sheets of canvas, and the frames are pressed tightly together by a screw press to render the joints water-tight. The juice is forced through pipes into one side of the press, and through the canvas of the frames, depositing the lime on the fabric and pouring out on the other side into troughs an almost clear liquid. Though this liquid has lost much of its original matter in solution, it is still far from the purity necessary to crystallize. It flows from the troughs into a receiving-tank for cooling.

At this stage it is plain that the clarified juice is a mixture of pure sugar and pure water, the sugar varying in proportion according to the richness of the beets, the fidelity of the machinery, and the watchfulness of the

operators. To extract the water from the juice, thus converting it into a rich syrup, is the next process, and is an interesting one. The juice is pumped into multiple-effect vacuum evaporators, so called because the heating effect of the steam is utilized *in vacuo* as many times as there are pans in the series. Steam is supplied to the first pan, and the vapor from the boiling juice passes to the second pan, and so on through the series. From the last pan the vapor passes to a condenser kept in a constant state of vacuum by a continuously acting pump, from which it flows away, a dark-colored syrup. When it obtains a density of thirty-one and one-half to thirty-two and one-fourth by hydrometer test, it is pumped to storage tanks. There the syrup remains until drawn off as needed in the sugar mill, which is a distinct division of the manufacturing process.

While resting a moment to fix the various operations clearly and connectedly in the mind, let us direct attention to the testing-laboratory, which is a little annex on the second floor, and where the chemists are busy. Some are testing the juice at different stages; others are examining the brown syrup; while the fine sugar comes in for special tests, so that the product may be uniform in quality. It is all very important and illustrates the care and skill and cleanliness necessary to produce sugar of a high grade, which is the most profitable to make.

From the storage tanks the syrup is pumped to the fourth floor and admitted to the syrup-boilers, or " strike-pans," of which there are four. These are large cylindrical cast-iron vessels, provided with a vacuum pump, a condenser, and coils of copper tubing to which steam may be turned as needed. After condensation has taken place, and when the pans are about one-fourth to one-third full of fresh thick liquor, a charge of cool syrup is admitted, to cause the formation of minute sugar crystals, the size being controlled by the sugar-boiler, who regulates the boiling and the admission of fresh syrup so as to avoid the for-

mation of new crystals of " false grain." In about four hours after the beginning of the boiling and when the pan has become filled with a dense mass of sugar crystals, a " strike " is made. This is simply the emptying of the " strike-pan " of its contents into one of two V-shaped tanks just beneath the pans, and in which the mass is constantly stirred by mechanical paddles to keep it from hardening.

To separate the sugar crystals from the syrup that will not crystallize in the boiling, is the next process; and for this machines called " centrifugals " are used. Fourteen of these are placed directly beneath the V-shaped tanks, so that the mass flows to them through discharge pipes regulated by cut-offs. These machines are cylindrical metal vessels about three feet in diameter and two and a half feet high, fitted with solid bottoms, but with the walls constructed of fine wire-cloth supported by a perforated brass backing. The drums are hung on vertical shafts revolving at about fourteen hundred per minute. The drum being washed out to remove all stickiness and then polished bright, a mass of sugar crystals and the containing syrup is admitted until it is about half full. The electric motor which operates the drum is then started.

The process is very simple and the most interesting yet seen, because the vessel is open to the free circulation of air, and the transition going on in it can be plainly seen. The mass is at first a dark brown color, but as the drum revolves faster the mass rises on the walls and is held there by centrifugal force. The syrup being a liquid, though thick, is forced through the fine mesh of the wire-cloth, and passes off through the perforated back to tanks beneath. Watching the inside of the drum, we see the color change gradually from dark brown to a lighter shade, then to a yellow, and finally to a cream white, as the syrup leaves it. In about thirty minutes the syrup is entirely eliminated and the sugar clings to the walls of the drum, four or five inches thick. The motor is then

shut off and an operator scrapes off the sugar with wooden paddles, through a removable trap in the bottom to the receiving tank on the second floor. There the sugar is sprayed with water in which a little harmless bluing has been added to correct the yellow tint, and then it is ready for the final process to render it fit for culinary use.

This is the granulating process, which is done in huge drums, eight feet in diameter; through these the sugar falls, and is then caught up and mixed about, while a blast of hot air from steam coils is blown through. By looking through little windows in the chamber we may see the sugar tossed about inside. Finally, after twenty minutes of this treatment it has become fine white sugar, and passes to the storage bin, from which it is drawn to the barrelling room beneath. Eight or ten hours before, it was the sugar beet's sweet content; now it is the refined sugar on its way to the people's tables, to sweeten their breakfast-food, syrup their griddle-cakes, and supply the loaf for steaming-hot coffee, to say nothing of confections.

The syrup that will not crystallize in the boiling, and which was separated from the sugar in the centrifugals, is worked through a system of purifying machines and crystallizers entirely different from the machines so far shown. The purifiers, called "osmogenes," twenty-seven in all, are similar in shape and size to the pressure filters, although in operation they are different. In the osmogenes the thick syrup is forced by hot water under heavy pressure through cells, the walls of which are a certain quality of paper. This paper catches all foreign matter held in suspension in the syrup, as it passes through the sheets, and the liquid is then pumped into cooling tanks. After reboiling, with other syrup added, it is drawn into one of twelve huge crystallizers, which on the outside closely resemble Scotch boilers, but are entirely different in every other respect. The crystallizers weigh twenty-four tons each, and inside them are large paddles that

revolve slowly, keeping the mass constantly stirred. With an even temperature supplied by steam coils within, the mass, or a large proportion of it, crystallizes in five to fifteen days, and is then treated to the granulating process, as described. A small portion is sometimes boiled a third time, to bring it to the crystallized state.

In the packing-room on the ground floor is the last scene of intense activity. Here the barrelling is done, and it is a bustling place. The foreman is filling the barrels, regulating the flow from the bins above; some workmen are lining barrels with heavy paper, others are nailing in the heads of filled barrels; while still others are rolling the barrels into the storage building just beyond. The output is eight hundred barrels every twenty-four hours, or a single barrel every two minutes; yet what seems through a narrowed vision a great amount of sugar, is but as a drop in the bucket and a small drop at that. Greater New York would consume in about ten days the product of the entire run of about one hundred and ten days, and for a year's supply for the nation's metropolis, the output of thirty factories would be required. The great city, however, with its great refineries at its very doors, sees no beet sugar from the Middle West.

The farmer is the man who is most benefited by the industry, if he gives thoughtful care and proper cultivation to his beet crop. While the cost of caring for the beets averages about thirty dollars an acre, the returns are large, and it is no unusual thing for an acre to produce from sixteen to twenty tons with an average of sixteen per cent of sugar-content. Another advantage to the farmer is the fact that the price does not vary greatly; the basis is fixed by contract before the seed is planted, and it can not be changed. In an average year of richness in sugar-content the farmers receive from five dollars to six dollars and seventy-five cents per ton for the beets, the price being based on the percentage of sugar-content, as per rigid regulations and positive tests. Many farm-

ers have netted from fifty to sixty dollars per acre, although the average would not be so high.

The utmost cordiality exists between the sugar company and its farmer-friends, and the latter are being constantly aided in beet-cultivation. Where distances are too great for economical haul by wagons, or roads leading to the factories are impossible for heavy loads, the company has established weighing-stations, at railroad points within a radius of thirty miles of the factory. Spur sidings have also been put in at many scattered points, where cars are loaded; the weighing is done at the factory, a careful system of records of every carload being kept, to insure against errors. It is an encouraging fact that wherever sugar-making plants have been established in good beet-growing territory, farm lands have had an appreciable increase in value.

The food value of sugar and syrup when used in moderate quantities is undoubted. It is frequently observed that white people of the South, who naturally take to syrup as a more or less steady diet, have good clear complexions with general good health; and plantation negroes whose staple diet is "blackstrap" are the healthiest of their race. As a food for stock the same low grade molasses is important, and is often fed in large quantities, mixed with hay or grain, or sprinkled on cane tops to cattle, horses, and mules. The sleekness of the mules on Louisiana sugar-plantations, where molasses is fed to stock, is a good indication of its value.

In a discussion of the food value of molasses, Prof. H. M. Shilstone, a Louisiana chemist, is quoted as saying:

"The value of a food depends upon the amount of energy or heat into which it is capable of being converted by the body. In a number of dietary studies made in this country, it was found that 55 per cent of the food consumed was of vegetable origin, and 45 per cent animal. Analyses show that the nutriments of vegetable foods are largely starch, which furnishes the major part of the heat and muscular power of the system; therefore, starch,

or any food that will serve the same purpose, is of great importance in the support of the body.

"As all starch foods before being assimilated have to be converted into sugar by the digestive juices, we can readily see the advantage that molasses holds over starch products, such as potatoes, corn, etc. The sugars have been found to be the most readily digested of all the carbohydrates. As already explained, we can look upon molasses as the equivalent of starch which has been digested and made ready for absorption.

"Extensive experiments have been made on the products of the sugar cane as a means of nourishment during excessive amounts of muscular work, all of which have shown that they are well adapted to furnish energy and heat required. In every case, the users of molasses and sugar had greater endurance and could stand more hard work than those who were deprived of the diet, and owing to their rapid absorption by the body, these foods better fit a laborer for his work upon the completion of a meal.

"That these results are correct can best be demonstrated by a close examination of the daily food of a Southern negro. This consists of corn-meal, molasses, and a small portion of fat bacon, with the necessary liquids. In this combination of molasses with the other foods we find all the necessary ingredients for furnishing the energy and muscular tissue.

"As an increaser of body weight, during the experiments made with the negroes fed on a diet of molasses by the State Board of Health of Louisiana in 1907, one subject who consumed an average of a pound of molasses per day for thirty days, showed an increase of 10 pounds in weight.

"Such information as this would lead us to believe that as long as the South can produce her usual quantity of molasses per year, the country need not suffer from the need of food such as will fit working-men with energy and muscular power."

The third and final source of sugar obtainable in commercial quantities, that of the maple, is drawn on extensively, and the product, either as sugar or syrup, is used in all parts of the country where the sweet tooth is cultivated. The hard-maple tree grows freely in the north woods, especially in Northern Michigan, Vermont, and the southern provinces of Canada. In the bright warm

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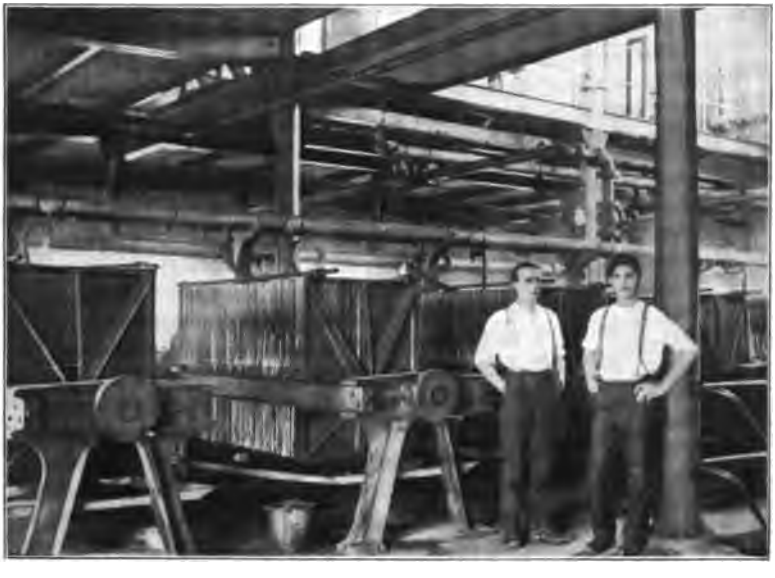
TWO OF THE GREAT SYRUP BOILERS OR "STRIKE PANS" IN WHICH THE SYRUP IS CRYSTALLIZED TO SUGAR



A SECTION OF THE TRIPLE LINE OF TWENTY-SEVEN "OSMOGENES," USED TO EXTRACT SUCH IMPURITIES FROM THE SYRUP AS WILL NOT CRYSTALLIZE IN FIRST BOILING

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days of March, when the winter snows are fast melting away and the nights are freezing cold, the sweet sap of the maple runs out, is caught and boiled down in the sugar-camp, and sugared, to meet the ever increasing demand from communities near and far. Years ago, before the industry had assumed commercial importance, the processes used were most primitive, and the product was a dark concoction, the flavor of which was a blend of maple sweet, liquid smoke, and dried leaves.

The sap was caught by alder spouts or spiles driven into holes in the trees, and gathered in open crocks, wooden pails, or buckets, and stored in open barrels. It was boiled in large kettles in the open air, which process was slow; and few of the pioneers made more maple syrup than enough for their own needs. There was little thought or care to produce nearly pure syrup, and most of it was very impure. As time passed, tin spouts replaced the wooden ones, and tin pails came in use, while long, flat metal pans took the place of kettles for boiling. The quality of the syrup was thus improved, and a much larger quantity could be made with the same amount of time and labor.

But the modern methods of making maple sugar have changed all that. The new-process evaporators, which have been in use in Vermont and Ohio, are now used in northern Michigan. The most complete camp in the north woods is situated on the banks of the Laughing Fish River, in Alger County. About two thousand trees are tapped in this sugar-bush, and the camp is situated on a gentle hillside slope overlooking a wide stretch of rough country. To insure cleanliness in gathering the sap, galvanized covered pails are used, which keep out leaves, snow, and rain-water; and galvanized tin tanks, holding three barrels and set on sleds, are hauled from tree to tree by teams of horses. From the tanks the sap is drawn off into pipe lines, also of galvanized metal, and flows down the slope to the storage tanks in the sugar

house. The modern sugar house is a neat enclosed building with a ventilator in the roof to draw off the steam from the evaporator.

The evaporator, which is the chief factor in the scientific making of maple sugar, consists of a sheet-iron arch seventeen feet long and five feet wide, upon which are set the pans for boiling. The arch is in effect an immense firebox with good draft to produce constant and intense heat. At the front end of the evaporator is a large pan with a corrugated bottom, giving a large boiling surface, into which all the fresh sap from the storage tanks flows. Running lengthwise of this pan are four narrow partitions, so arranged as to openings in them to the spaces thus formed, that the sap entering the pan at one corner must run four times the length of the pan before it can pass through a siphon into the smaller pan in the rear. There are three of these smaller pans in series, in the last of which the concentrated syrup is produced. An automatic regulator keeps the steaming-hot sap from the super-heater in exactly the right quantity to insure a uniform depth in all the pans all the time. As the pans boil, the fresh sap forces the partly evaporated or sweeter liquid toward the back. It becomes thicker and sweeter as it flows slowly on, until in the last pan it is nearly the consistency of syrup.

With clear pure sap gathered by hygienic methods and boiled in perfectly clean pans of white metal and watched over by careful syrup-makers, it is possible to make maple sugar of the highest standard of purity. Modern methods make it possible to handle two or three barrels of sap an hour, and that sap is boiled to syrup in from two to three hours. Syrup made quickly by the evaporator process is of a lighter color and of better quality than that boiled more slowly by primitive means.

IV

PAPER

FROM PEAT AND WOOD PULP TO PAPER

EGYPTIAN METHODS OF MAKING PAPER FROM PAPYRUS — SOME ANCIENT DOCUMENTS ON PAPYRI — PAPYRI FOUND AT POMPEII AND HERCULANEUM — EARLY PAPER-MAKING BY THE CHINESE — VARIOUS MATERIALS USED — PAPER-MAKING BY THE MOORS IN SPAIN — LINEN PAPER OF THE 14TH CENTURY — WOOD SUGGESTED BY RÉAUMUR — FIRST PAPER-MILL IN AMERICA — INVENTION OF PAPER-MAKING MACHINERY — VARIOUS PAPER-MAKING MATERIALS — CONDITIONS OF PROFITABLE MANUFACTURE — UTILIZATION OF WASTES — DEVELOPMENT OF PAPER-MAKING IN THE UNITED STATES — PAPER-MAKING IN THE WILDERNESS — FROM LOGS TO PAPER — FROM RAGS TO PAPER — FROM PEAT TO PAPER — USES OF PAPER IN THE INDUSTRIAL ARTS.

OF all the arts and sciences which have come down to us from the early civilizations, the art of making paper is probably the oldest. It had its beginning with that most ancient paper of the Egyptians, called papyrus, and is represented on the monuments of that age in the form of long, narrow sheets, which were rolled up, and on which the scribe wrote with a reed, called *kash,* dipped in red or black ink made of animal carbon. The sedge-like plant, papyrus, grows in swamps along the banks of the Nile, and not in the stream itself, as has been supposed. Its root is large, hard, and creeping, while the stem (of cellular form) is soft but strong, eight to ten feet in height, and as thick at the lower part as a man's arm. Near the upper extremity the stem becomes triangular and terminates in a wide-spreading and beautiful umbel of extremely numerous drooping spikelets, each containing from six to thirteen florets, and with a gen-

eral involucre composed of eight large sword-shaped leaves.

The plant was known to the ancient Egyptians as *papu;* to the Greeks as *byblos* or *deltos;* and to the Hebrews as *gomé.* Its modern Arabic name is *berdi.* Although growing in profusion from the remotest antiquity, in more modern times the plant has become very rare. Bruce, in his travels between 1768 and 1773, observed it in two places: on the lower and upper Nile, and on the Jordan; and later travellers discovered it during the first quarter of the last century in some of the western rivers of the continent, and in Sicily, where it grew wild. In more recent times it has been found on the banks of the Anapus and in the pools of the Liane, near Syracuse, where experiments of the most ingenious character have been made on making it into paper.

Since the earliest use of paper was for the purpose of writing, and the first material from which it was made was papyrus, it is of interest to note the methods used by the ancient Egyptians in making it. The inside of the stem of the plant consists of a cellular tissue or pith, the portion immersed in the water and mud being whiter and more compact. Under the outer skin a number of thin pellicles are found lying one above another. In making papyrus these pellicles were removed, laid side by side with their edges overlapping; other layers of the same were placed crosswise over these, according to the thickness desired; the whole was pressed under heavy stones; and the sheet thus formed was dried in the sun. The various layers of the papyrus become thinner toward the centre of the stem, and to this fact were due the different qualities of paper produced. From the innermost layer of membrane was made the finest quality, called *Hieratica,* or paper of the priests. Being made by the Egyptian priests its sale was interdicted by them until covered with sacred writing. It then became an article of trade, and a means being found to remove the writing, the sheets

were sold in Rome under the name of *Augustus* paper. A second quality was made and called *Livia* paper, after the wife of Emperor Augustus, as it was supposed that the first quality was named after him. Another quality when imported to Rome was remanufactured by Palæmon, a schoolmaster and paper-maker, who reduced its thickness by a process of his own, thus making it equal to the first quality, and it was called *Fanniana*.

Pliny, who gave these interesting particulars, contended that in the making of papyrus the Nile water was required, since "when it is in a muddy state it has the peculiar qualities of glue, and the various kinds of paper are made on a table where they are moistened with this water." This was an erroneous idea, however, since the whole merit lay in using the membranes when fresh, while their natural gum was soft enough to make them adhere together. When newly made, papyrus was white or brownish white, and flexible, but those papyri which have survived the ravages of time to the present day are light or dark brown in color, and so brittle as to break on being touched. The scapus, or roll, usually consisted of about twenty sheets of papyrus glued together at the ends, and was about thirteen inches wide.

Some of the remaining Egyptian papyri, as they are called, are as old as the sixth dynasty (about 3,000 B. C.), and owe their preservation to the way in which they were deposited, and also to the peculiar dryness of Egypt. Those of a religious nature have been found upon the bodies of mummies, and sometimes, indeed, between the bandages, or even spread like a shroud over the whole bandages. During the nineteenth and twentieth dynasties papyri were deposited in wooden images of the god Osiris, and placed near the mummies. Papyri of a civil nature were packed in jars and also laid near the dead. The Egyptian papyri are divided into three classes, namely: I. Hieroglyphic, accompanied by pictures of deities and relating to the ritual. This class in-

cludes solar litanies, describing the sun's passage through the hours of the night; and the Ritual, containing mystic allusions supposed by the ancients to have been written by the god Thoth himself. II. Hieratic papyri, written in the cursive hand of the Egyptians, comprise a more general literature, religious, civil, and magical. Some of these papyri contain directions for the preparation of charms and amulets; others relate to the campaign of Rameses II against the Hittites; and others contain works of fiction. III. Demotic papyri, written in the enchorial character, comprising rituals, contracts for the sale of land and mummies, accounts and letters, and other documents often bi-lingual and sometimes accompanied by hieratic and Greek versions. Libraries of papyri seem to have existed at all times in the history of Egypt, and, under the Ptolemies, it is believed they contained as many as seven hundred thousand rolls.

"Besides the papyrus, there are remnants of ancient paper made of the inner bark of trees, which, however, does not seem to have been so general, on account of its brittleness. The papyrus seems to be better fitted to resist the tooth of time than any other writing material. To give a single instance: M. Saillier, at Marseilles, who possessed a number of Egyptian papyrus manuscripts, had two rolls, which Champollion the younger, when embarking for Egypt in 1829, discovered to contain the history of the wars and reign of Seostris the Great; their date is that of the ninth year of his reign. But Seostris-Rhamses, or the Great, according to the calculations of German chronologists, lived in the time of Moses; being, it is supposed, the son of the Pharaoh who perished in the Red Sea. Whatever may be thought of the date assigned to these manuscripts, it is certain that their age is very great."

The interesting class of papyri discovered in the ruins of Pompeii and Herculaneum reveal the condition and arrangement of a Roman library. The cylindrical rolls were from eight and one-half to twelve and three-quarters inches wide, with their titles written on a strip in

red letters, while the writing was generally on lines ruled with a substance resembling lead. They were packed snugly in a perpendicular position in a cylindrical bronze chest, and when wanted were taken out single and read by unrolling from one end. They seem to have been sold at various prices, very old papyri, like old books, being held of immense value and brought high figures, but the works of authors of the time were not much more costly, considering the standards of value then used, than modern books. Of all the extensive private and public libraries which once existed in Greece and in Rome, none remain except those exhumed from Herculaneum. In 1753 a library containing nearly eighteen hundred papyri was uncovered in a small house, and, although the rolls were burned to a cinder, many of them were unrolled in Naples by a laborious process requiring great skill and care. They were found to consist of the works of philosophers of the Epicurean school, and did not fill the literary expectations formed of them. They were written on one side only, and many were in Latin, which added to the difficulties of unrolling and deciphering them.

From an early date in the history of the papyrus industry the business was centred in Alexandria, and so extensive did the trade become that the city greatly increased its wealth by its commerce in this article. Papyrus was in fact the paper of the period, but, although mentioned by some of the early Greek scribes, it was not in universal use by their countrymen until after the time of Alexander the Great. It was then extensively exported from the Egyptian ports, but was always an expensive article to the Greeks, a sheet of it costing as much as the value of a dollar. Nor is there any evidence to show that it was used by the Romans at an early period, although it is known that the papyrus plant was cultivated in Calabria, Apulia, and in the marshes of the Tiber, and there is reason to believe that the Sibylline books were written on it. At a later date, however, the

staple was undoubtedly imported from Alexandria, and remade and improved by the Roman manufacturers. In the time of Hadrian the papyrus industry in Alexandria had assumed such proportions as to cause him, it is said, to exclaim in wonder at its extent, when he visited that city. For several centuries after, it continued to be an important article of trade, but in the later periods it was no longer made into rolls, but was cut into square sheets and bound into books.

About the beginning of the Christian era the art of making paper in the modern sense, by the pulping of fibrous substances, was well established by the Chinese. From the remotest antiquity they had employed a style or sharp point upon dried palm or other leaves in writing public documents and other records. The use of such materials, or possibly the operations of paper-making wasps and other insects, may have suggested the idea of reducing the substances to a fine pulp, spreading it thinly over a smooth flat surface, and drying it out under pressure. It is probable that they used a variety of materials, but the principal ones were the bark of certain trees, the soft part of bamboo stems, and cotton. These they fabricated into a rough and crude sort of paper by processes which have long since been lost in the vista of time. It is certain, however, that they transmitted their knowledge of making paper from cotton to the Arabs who, in the early part of the eighth century, or about 704 A. D., began its manufacture at Samarcand. The art spread rapidly through the empire, and there are many Arabian manuscripts still in existence bearing date of the ninth century.

In Europe the making of paper was begun by the Moors in Spain, and with the occupation of Sicily by the Arabians, the industry became well-established there, though the only kind produced was that made from cotton. But with the downfall of Moorish power in Spain, the industry declined and almost ceased for a time. It

was revived, however, and in the twelfth century Spain became the greatest paper-making country, and Italy was second in importance. Before the tenth century the papal bulls issued in Rome were written on the native paper, and a few centuries later the Italians were famous for the excellence of the paper they produced. From Spain the ancient art was introduced into France about the year 1189, and so rapidly did the industry spread through the country, that the production soon exceeded the home consumption and a considerable surplus was exported. By the fourteenth century Germany had become one of the important paper-making countries, and a century later this and France ranked first and second, with Holland a close third. During these centuries England had been content to import her paper supplies; not until the close of the fifteenth century was the first paper mill built there, and for more than fifty years it was the only one. The oldest existing document written on cotton paper is a deed of King Roger of Sicily, bearing date 1102, but there is in Vienna a charter of Frederick II, of date 1228, on paper of this material. Its use was soon after prohibited for official documents, and a kind of vellum substituted. This was often of a blue tint; and the writing, which was very elaborate, was done in gold. Many of the old manuscripts still preserved in Venice are on vellum, of which that of the Gospel of St. Mark is a good example.

The exact date when linen was first used for making paper is uncertain, but is believed to have been at an early time. Perhaps the best evidence is presented by Abdollatiph, an Arabian physician, who visited Egypt in 1200. He wrote: "That the cloth found in the catacombs and used to envelop mummies, was made into garments or sold to the scribes to make paper for shopkeepers"; and as there is no doubt that these mummy-cloths were linen, it proves that the use of this material is of no mean antiquity. The change of materials

occurred in Europe about the opening of the fourteenth century, and less than a century later almost all the paper there used was made of linen, the cotton paper industry being confined to the south of Europe. It is more than probable that linen paper was first used in Germany, since the archives of the hospital of Kaufbeurn contain documents made of it of date as early as 1318. There is no evidence, however, in the libraries of Spain or Italy to show that linen paper came into use in those countries before 1367. In all later ages the paper made from this material has been held the highest grade because of its firmness and durability.

The saving of rags and paper scraps for making paper was not practised in those times, and it was only by much coaxing that the world could be induced to keep all such wastes for that purpose. As long ago as 1471 a curious petition of the Pope appeared asking for the collection of sufficient rags to make paper on which to print about twelve thousand volumes of sacred writings. Somewhat later an act of Parliament was passed providing that the dead should be buried in no other than wool garments; and, although it was intended to foster the wool trade, it had the effect of saving two hundred and fifty thousand pounds of linen yearly for paper-making. From this beginning of more or less enforced decrees the practice of saving waste materials slowly spread over Europe, and in time the old-fashioned rag-picker, with his bags and rickety hand-cart, came to be the mainstay of the paper-maker. To this day, indeed, he is a busy agent in the collection of those wastes which enter into the manufacture of the better grades of paper, as well as of the common kinds that are used for wrapping and boards. But it was not until the beginning of the nineteenth century that a way was found to work up old books and scrap-paper into new.

It was about 1719 that the idea of making paper from wood and other fibrous materials, such as straws, grasses

and wild growth, was suggested by Réaumur, as a result, it is said, of his observations and study of the fabric of wasps' nests. A number of years after, in 1788, a French paper-maker made several quires of paper from the bark of the sallow-tree, for which he received a silver medal. It was a century later, however, before wood-pulp paper was manufactured on a commercial scale. In 1850 *Lloyd's Weekly,* of London, introduced a paper made from esparto — a Spanish grass — which later was largely used by the paper-makers of Great Britain, although the process of making required large quantities of chemicals, among which was caustic soda. The beautiful rice paper made by the Chinese more nearly resembled the ancient papyrus than modern paper, since it was composed of thin slices of the pith of the plant *Aralia papyrifera.* The pith was obtained from the stems in rolls from one to two inches in diameter and several inches in length, the skilful Chinese workman slitting the stem with a sharp, straight knife, and paring the pith from the circumference toward the centre, making a rolled layer of uniform thickness. This was unrolled and placed under weights until smooth and flat. A number of these pieces were joined together to make sheets.

As the texture of paper became finer, affording a smoother writing surface, distinctive water-marks were made in the sheets, the impressions woven into the fibres of the paper being of the makers' names, often elaborate designs of animals, birds, flowers, heads, armorial bearings, and of domestic and warlike instruments, for a full expression of their artistic tastes. Although England was slow in promoting the paper industry, by the early part of the nineteenth century it made the finest paper produced, having brought the art to a high state of perfection in respect of whiteness, strength, and quality of texture. France also made fine paper, while Italy and Germany made the cheapest paper which though durable was not so fine.

The first paper-mill established in America was built by a German, William Rittenhousen by name, in 1690. It was located on the banks of a small stream tributary to the Wissahickon, near Philadelphia. About 1730 the industry had a beginning in New England, the first paper-mill being put up near Boston; but for nearly one hundred years later, the paper industry was centred in the former city, as Pennsylvania, New Jersey and Delaware were the largest producing States. Philadelphia was then the literary centre of the United States, from which radiated through its publications the advanced knowledge of the world. Benjamin Franklin alone established eighteen paper-mills near that city; and it is said that in 1770 there were forty mills in operation.

During these centuries of primitive methods in manufacturing, the paper-making industry struggled along under the most crude processes, but in 1799, Louis Robert, of Essonnes, France, invented a machine which instilled new life into the trade. Three years later the paper machine was brought to England, presumably by St. Leger Didot, and afterwards improved by Fourdrinier, whose name it has borne ever since, despite the fact that Bramah took out a patent more than a year earlier for very similar improvements. This was in 1805, and the value of the invention and the process of manufacture were quite clearly given in an old print of the time:

"The combination of flexible fibres by which paper is produced, depends on the minute subdivision of the fibres, and their subsequent cohesion. Linen and cotton rags are the common materials of which paper is made, but hemp and some other fibrous substances are used for the coarser kinds. These materials, after being washed, are subjected to the action of a revolving cylinder, the surface of which is furnished with a number of sharp teeth or cutters, which are so placed as to act against other cutters fixed beneath the cylinder. The rags are immersed in water and continually exposed to the action of the cutters for a number of

hours, till they are minutely divided, and reduced to a thin pulp. During this process a quantity of chloride of lime is mixed with the rags, the effect of which is to bleach them, by discharging the coloring matter with which any part of them may be dyed. Before the discovery of this mode of bleaching, it was necessary to assort the rags, and select only those which were white, to constitute white paper. If, however, the bleaching process be carried too far, it injures the texture of the paper by corroding and weakening the fibres.

"The pulp, composed of the fibrous particles mixed with water, is transferred to a large vat, and is ready to be made into paper. The workman is provided with a mould, which is a square frame with a fine wire bottom, resembling a sieve, of the size of the intended sheet. With this mould he dips up a portion of the thin pulp, and holds it in a horizontal direction. The water runs through the interstices of the wires, and leaves a coating of fibrous particles in the form of a sheet, upon the bottom of the mould. The sheets thus formed are subjected to pressure, first between felts or woollen cloths, and afterwards alone. They are then sized, by dipping them in a thin solution of gelatine, or glue, obtained from the shreds and parings of animal skins. The use of the size is to increase the strength of the paper, and by filling up its interstices, to prevent the ink from spreading among the fibres by capillary attraction. In blotting paper the usual sizing is omitted.

"The paper, after being dried, is pressed, examined, selected, and made into quires and reams. Hot-pressed paper is rendered glossy by pressing it between hot plates of polished metal. By the ingenious methods invented by Fourdrinier, instead of the use of moulds, the pulp is received in a continuous stream upon the surface of an endless web of brass wire, which extends round two revolving cylinders, and is kept in continual motion forwards, at the same time that it has a tremulous or vibrating motion. The pulp is thus made to form a long, continuous sheet, which is wiped off the wire web by a revolving cylinder covered with flannel, and, after being compressed between other cylinders, is finally wound into a coil, upon a reel prepared for the purpose.

"Another machine for making paper consists of a horizontal revolving cylinder of wire-cloth or web, which is immersed in a vat to the depth of more than half of its diameter. The water

penetrates into this cylinder, being strained through the wire web, at the same time depositing a coat of fibrous particles on the outside of the cylinder, which constitutes paper. The strained water flows off through the hollow axis of the cylinder, and the paper is wound from the part of the cylinder above water, in a continuous sheet."

From these simple but practical methods of making paper by machinery, there have been evolved the great ponderous machines in use at the present time, turning out tons upon tons of finished paper every day, the features and operation of which will be dealt with further on.

In this progressive age in the development of the earth's material resources and the utilization of wastes, nearly all kinds of wild and cultivated plants have been used experimentally or on a manufacturing scale, for making paper. It has been found, in fact, that practically all fibrous materials of the vegetable world will make paper, of one kind or other, and of different grades. But there are so many factors in the conduct of the industry, some of which are of an adverse nature, that only a few of the raw materials which might be employed, can be used on an economic basis. Before citing these conditions, it may be well to state as a general rule, that the percentage of fibre sufficiently resistant to withstand the action of chemicals governs the quantity of paper produced, while the length, strength, and felting qualities of the fibres and the chemical nature of the cellulose they contain, determine the quality. From this it is clear that the best grades of paper, which are hard and tough with good wearing qualities, and do not discolor with time or use, are made of materials having long and strong fibres, which contain nearly pure cellulose. Then there are the conditions of an unlimited supply of the raw material not far removed from the markets for the finished product, and abundance of pure water and large quantities of the power required in the manufac-

turing process. The prices at which paper is sold is also a governing factor, since many of the paper materials can be made into other products commanding much higher prices and bringing larger margins of profit.

The raw materials for paper-making as it is conducted to-day may be divided into six groups, namely:

I. Seed hairs, cotton the only representative.
II. Bast Fibres, such as flax, jute, hemp, ramie, China grass, common nettle, paper mulberry, Manila, and other flax.
III. Whole stems and leaves of straws and grasses, such as corn, sugar cane, bamboo, other wild and cultivated grasses, cotton stalks.
IV. Various kinds of wood, such as spruce, hemlock, poplar, and cottonwood.
V. Peat, the fibrous accumulations of ages in bogs.
VI. Rags and paper wastes, collections from the four-corners of the earth.

Nearly all the materials comprised in the first three classes come to the paper-makers in the form of factory wastes from other industries, those of seed hairs and bast fibres being scutching, mill, and rag wastes of the textile industries; while those of the third class are the natural wastes of agricultural products. Bamboo, esparto, and paper mulberry, however, are not wastes, but are gathered primarily for paper-making, as they produce paper of greater value, in strength and durability, than could be realized from other products made from them. New cotton fibre, and "linters" (which is a preliminary product of the cottonseed-oil industry), although perfectly suited for manufacture into high-grade paper, are no longer used for this purpose, as the price at which it would have to be sold is prohibitive. Almost all the materials comprised in the second class are now impossible materials for paper-making, as they are worth from three to twenty cents a pound for manufacturing cloth, bagging, ropes, and cordage. Other conditions

exist as to straws, which at an initial cost of five dollars a ton at the paper-mill cannot compete with wood at eight dollars a cord for making white paper; and this also applies to cornstalks, sugar cane, and like substances, all of which will make acceptable grades. Peat, of which there are inexhaustible supplies distributed throughout the world, offers the latest material for the making of wrapping paper and boards, its use for this purpose being of recent years. Rag and paper wastes, which are now collected in large quantities, go far toward supplying the fibres for certain grades of paper and boards.

These conditions of both a physical and a commercial nature in the economic production of paper, naturally throw the industry upon the resources of the fourth class, or wood pulp; for more than twenty years standing timber, chiefly spruce and poplar, has provided the greater part of the material for the paper made in the United States. In 1907, nearly four million cords of these woods were used, yielding — on an average of twelve hundred and fifty pounds of pulp to a cord of wood — about two and a half million tons of pulp. This made eighty per cent of the paper and boards produced. Other woods used were: Hemlock, 576,000 cords; pine, 78,000 cords; balsam, 44,000 cords; cottonwood, 66,000 cords; and red and white fir, larch, gum cypress, beech, birch, maple, basswood, buckeye, and chestnut, 125,000 cords. The comparatively small quantities of the miscellaneous woods used was due to the scarcity of such timber within a reasonable shipping distance of the paper-mills, and also to the fact that they were of greater value to the wood-working industries. Then, too, the soft, or coniferous, woods have longer fibres than those of the hard, deciduous woods, and consequently are preferred by the paper-makers. Although both spruce and poplar may be treated by either the sulphite process or the soda process, spruce is usually reduced by the sulphite process, while poplar takes the other.

Wood, after all, is the cheapest material that paper-makers of the present day have found; and this is due to its low initial cost, ease of transporting it to the mills, usually by floating the logs down some stream, economic handling by modern machinery, and uniform supply free from dirt. A supply of standing timber sufficient for a number of years' run of the mill and contiguous to it, is the first consideration in selecting its location, for the initial investment in a modern paper-mill is very large, and those not favorably situated near available supplies cannot compete with the mills having large forest reserves. Some of the largest paper-producers in the United States conduct forestry departments that restrict the cutting of trees in millions of acres of forest, to the size suitable for the machinery employed in the mill, and also plant and grow many thousands of trees yearly. The next important consideration is the water-power possible of development from the rivers and streams of the region, since a large amount of power is required in driving the grinders and the ponderous machinery of a modern paper-mill. There must also be an abundant supply of clean white water, as much of it is required in the making, and great quantities of steam must be generated for the "cooking" process. The cost of cutting the timber and getting it to the mill, making the paper, and transporting it to the markets in competition with other producers, are other factors to be taken into account.

The cost of paper of whatever kind or grade laid down at the point of consumption is another factor in the trade, and there are localities where very unusual materials are worked up into paper for domestic supplies, because the long haul and high freights bar the paper made at a distance. This is particularly true of low-grade papers, boxboards, and like grades of heavy stock, as all straws and other cheap fibrous materials are suitable and to be had in large quantities in almost every part of the country. It is simply an economic balance of trade with

the cost of production in a favorable location plus the freights on the one hand, and the cost of production on a smaller scale at or near the point of consumption, on the other.

When all these conditions have been carefully weighed, there still remains a problem to be solved, namely, whether the material intended for use can compete economically with various other materials used by other producers in making the same kind or grade of paper. This is often a vexed question, and to determine the relative values of different raw materials, samples are examined and analyzed in the laboratory. This is done not only to arrive at their adaptability to paper-making, but for a fairly accurate idea of the quality of paper they will produce, the cost of treatment, and such details as the time and pressure required for cooking, and the quantity of chemicals needed in that and the bleaching process. The quantity of paper obtained from a given weight of raw material being known, and, of course, the quality of paper, the market value of the material is easily estimated. All this saves much time and cost in the mill. In a general way all materials are valued by comparison with rags and other wastes which are the standard for writing paper and other high grades, or with wood-pulp which makes a good grade of white paper, such as news, print, wrapping, and the cheaper kinds, of which there is a large consumption.

Although the cost of chemicals needed to produce a ton of paper is greater for wood than for any other material, and the time of cooking is longer, these are offset by wood's cleanness, its having low digestor requirements, as much more wood can be put into a digestor than of any other material, and the pulp's less need of beating than that composed of longer and stronger fibres. It is primarily the cost of the raw materials rather than the mill treatment that determines their availa-

bility in the economic production of paper. The cost of raw materials required to make one ton of paper:

Material	Cost per ton at mill	Yield in paper per cent	Cost of material per ton of paper
Wood	$ 6.00 to $ 8.00	40	$10.00 to $ 13.25
Cotton stalks, straw, etc.	2.00 to 5.00	35	5.75 to 14.33
Old bagging	16.00	80	20.00
Scutching waste	20.00 to 40.00	80	25.00 to 50.00
Linters	20.00 to 60.00	80	25.00 to 75.00
Waste paper	10.00 to 40.00	90	11.00 to 44.50
Rags	20.00 to 120.00	80	25.00 to 150.00

It is generally the greater cost of production, which is often due to the value of the raw materials, coupled with the lower quality of the finished product, that renders impracticable the use of many wild and cultivated plants, which otherwise might be made into some grade of good paper.

Of the annual production of paper in the United States, which amounts to more than three million tons, about eighty per cent or two million four hundred thousand tons, becomes waste material in three to five years. A large proportion of this waste might be recovered at a cost of collecting it that would permit of its use, but, as a matter of fact, only about twenty-five per cent, or six hundred thousand tons, reaches the paper-mill for re-making. The waste consists of new paper trimmings and clippings, writing and newspaper, wrapping paper and pasteboards, old books and scraps, which, though not suitable for making high-grade papers, can be used very readily for wrapping, cover, and blotting paper, and for boards, for which there is always a large market. The wholesale prices of such waste ranges from two dollars a hundredweight for high-grade clippings, one dollar for new paper stock, sixty-five cents for folded news-papers, to twenty cents for common scraps. At an average of half a cent a pound the amount of waste that could easily be recovered would be valued at ten million dollars annually, and would make all the building, bagging,

blotting, and cover papers, and all the boards used in the United States.

In the large commercial centres of the Southern States, especially those at or near tide-water, but far removed from the chief points of paper-production, some of the cheaper grades of paper, for which there is a large demand, might be made from the abundant supplies of rice straw, which are now wasted, at a less cost than they can be made by the paper-makers in the North and shipped to the Southern trade. Likewise, waste flax from three million acres cultivated for the seed in Michigan, Wisconsin, Minnesota and Dakota, at one ton of straw to the acre would produce six hundred thousand tons of fibre, which would make four hundred and eighty thousand tons of strong, high-grade paper. This flax straw can be delivered at the mill for two and a half to three dollars a ton, while other straws cost from five to six dollars; and flax straw is one of the best paper-making fibres if obtained without seed, and produces paper commanding a high price.

As a comparison of values, it may be stated that the worth of the wastes from the textile industries of this country exceeds the value of the entire rye crop, is one-twentieth that of the wheat crop, one-third that of the products of the saddlery and harness industry, one-half that of hardware, and fully equal to the fur goods trade. Practically all the wastes from textiles are utilized in one form or other, but, for various reasons the paper-makers do not get it all. Rags, which are worth from two to five cents a pound according to cleanness, color, and wear, bring nine million dollars each year; and it is estimated that three times the amount could be recovered. If all the wastes of textiles and paper were saved and reclaimed for new paper stock, other materials would be conserved, which would be of still greater economic value.

Although much of the waste of the lumber industry, both in logging and in the sawing, might be utilized in

paper-making, very little of it is so used. The wasteful methods of logging, by which all refuse is left in the forest to rot or breed fires, leave no chance of recovering some of the wood which might be available for working up into pulp. On the other hand fully twenty-five per cent of the tree which has been cut for lumber is still of use for making pulp. But the waste which comes from the saws such as slabs, edgings, and other trimmings, is made into lath and other small articles, or cut into firewood, for which a good price is obtained at points entailing a short freight haul. The present methods of removing the bark, rotten wood, and knots, in the sawmill, necessitate much handling of the material to render it fit for treatment in the paper-mill. If this could be obviated, and the lath stock used for paper-making, twelve million cords of wood would be available annually, and could be obtained by paper-mills situated adjacent to the sawmills, at a lower cost than wood direct from stumpage.

If, as has often been said, the consumption of paper is the true measure of the people's culture and learning, no better evidence of American progress in this regard is to be found, than the facts and figures of the development of this industry, covering a period of a little more than one hundred years. The remarkable growth of newspapers in that time is, perhaps, the best criterion to emphasize the great strides which have been taken in the enlightenment of the world through the printed page. Away back in the days when the colonies were fighting for independence, the number of newspapers was thirty-seven, with a combined circulation of forty-eight thousand. Among these the first to be published was in Massachusetts in 1704, in Pennsylvania the event occurred in 1719, in New York in 1725, in Maryland in 1728, in South Carolina and Rhode Island in 1732, in Virginia in 1736, in Connecticut and North Carolina in 1755, in New Hampshire in 1756, in Delaware in 1761. A cen-

tury and a quarter after the independence of the United States had become established, the newspapers in the country numbered more than twenty thousand with a total circulation running into billions. The development of American literature through the medium of magazines and books, is scarcely less marked. So great indeed are the requirements of the publishing world that the amount of paper used annually of the news and book grades, is nearly one-half of the total consumption of all other kinds in the country. As an instance of the insatiable demand of the book-makers, it may be cited that nine novels, which sold to the extent of one million six hundred thousand copies, required in making two million pounds of paper, or one thousand tons, which would fill thirty-five standard railways cars, comprising an entire train. Four thousand trees were cut to furnish the wood-pulp needed for this quantity of paper.

The United States is the largest paper-producing nation of the world, with an annual output (1905, last Government report) of 3,106,696 tons, the consumption just about equalling the supply. Of the total production the news amounted to 912,822 tons, the book to 515,547, the fine, including writing, to 146,832, the wrapping to 644,291, the boards to 520,651, and all other kinds 366,553 tons. The aggregate value of these stocks was $188,715,189, including wood-pulp and fibre made for sale, and all other products. Although the industry is carried on to a greater or less extent in almost every State, for economic reasons already explained, the bulk of the production is in twelve or fourteen of the Eastern and Middle Western States. This is due to the concentration of the business into great corporations, with the paper-mills located near the supplies of raw material, and at the same time in many instances close to the points of largest consumption. There are the vast forests of northern New England supplying the wood-pulp, and the textile industries the wastes, for the mammoth paper-

mills in those States, while within reasonable shipping-distance are the great centres of consumption, such as Boston, New York, Philadelphia, and other cities of the East. Out in Wisconsin, Michigan, and Minnesota are other large plants near the sources of wood-pulp, which make paper and boards for the immense trade of Chicago and for other cities of the Middle West. One corporation alone, with a capital of one hundred and ten million dollars, operates thirty-two paper-mills having ninety-six paper-making machines running continuously.

The following table gives the production by States of the principal kinds of paper, in tons, and their values, for the year 1905.

In analyzing this table, in which the States are arranged in order of the aggregate value of all their paper products, it will be observed that in the production of newspaper, which is of the greatest tonnage but of somewhat less value than any other kind, New York is the leading State followed far behind by Maine, Wisconsin, and New Hampshire, in the order named. New York alone produced thirty-eight and one-tenth per cent of the total quantity, and thirty-seven and five-tenths per cent of the total value of this paper. In the making of book paper Massachusetts is far in the lead, producing twenty-one and five-tenths per cent of the total quantity, with Maine, Pennsylvania, Michigan, and Wisconsin following in order of values. The manufacture of plate, lithograph, map, woodcut, and similar papers decreased largely from the report of 1900, the total value in 1905 being $1,458,343, or a percentage of decrease of twenty-seven and eight-tenths. The average value of book paper that year is figured at seventy-one dollars and seventy cents a ton.

In the manufacture of fine papers, including writing, which is fourth in importance, Massachusetts is the largest producer, with an output in point of value of sixty-seven per cent of the total. Pennsylvania, Wis-

State	News		Book		Fine		Wrapping		Boards		Other Paper Products		Wood Pulp and Fibre	Value all Products
	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Value	
New York	347,546	13,465,093	44,515	2,814,271	55	6,604	157,186	7,180,993	90,094	3,347,317	80,644	4,886,128	6,050,205	37,750,605
Massachusetts.	19,659	904,769	123,508	9,891,151	80,775	14,971,411	16,150	1,417,915	27,020	1,338,346	29,112	3,013,778	474,877	32,012,247
Maine	215,307	7,721,864	67,397	5,159,239	4,400	385,000	89,818	4,075,497	13,477	523,568	2,525	104,596	4,981,360	22,951,124
Wisconsin	121,749	5,187,635	52,283	2,839,787	17,333	2,066,243	94,454	4,200,058	167	4,592	10,618	772,442	2,773,417	17,844,174
Pennsylvania..	1,140	50,445	68,163	5,193,981	22,095	2,322,427	58,192	3,154,038	26,398	688,358	80,099	2,710,813	1,290,970	15,411,032
Ohio.....	4,104	190,600	21,461	1,664,079	8,722	1,057,920	44,037	1,786,172	60,269	1,716,740	46,038	3,606,626	939,390	10,961,527
New Hampshire.....	80,522	3,176,191	12,039	814,679	414	18,677	27,141	1,184,128	8,268	350,277	2,681	304,374	3,081,965	8,930,291
Michigan	8,167	337,747	52,308	3,647,183	2,647	256,062	32,654	1,565,861	26,382	812,781	6,179	255,090	465,907	7,340,631
New Jersey			4,720	330,417			18,720	1,471,713	37,692	1,174,348	29,844	1,635,119	431,865	5,043,462
Connecticut ...			6,009	585,879	6,439	864,055	7,056	502,544	64,610	2,354,053	5,535	695,800	36,816	5,039,147
Indiana.....	7,315	316,764	1,807	119,424			28,144	874,463	83,414	2,217,116	24,222	382,871	6,360	3,916,998
Vermont	34,396	1,397,204			948	54,785	17,633	891,106	4,599	183,764	13,859	955,567	349,082	3,831,448
Maryland.....			28,827	1,986,753			1,084	29,188	4,174	112,207	7,035	282,673	885,527	3,296,348
Virginia	1,576	77,180	11,026	724,158	166	12,956	2,450	104,600	4,199	161,658	3,344	373,183	1,580,660	3,034,395
All other States	71,341	3,080,968	21,484	1,632,500	2,838	233,030	49,572	1,997,316	9,888	1,674,432	24,818	713,086	1,720,428	11,351,760
Total	912,822	35,906,460	515,547	37,403,501	146,832	22,249,170	644,291	30,435,592	520,651	16,659,557	366,553	20,692,140	25,068,769	88,715,189

consin, and Ohio also produced fine papers amounting to considerable value. The writing papers averaged one hundred and forty-six dollars and forty-four cents a ton, while Massachusetts reported a valuation of one hundred and seventy-six dollars and twenty-six cents a ton. In wrapping paper New York takes the lead with a percentage of twenty-three and five-tenths of the total output, which is more widely distributed among the States, Wisconsin, Maine, Pennsylvania, Ohio, and Michigan being large producers. The average value is shown as forty-one dollars and sixty-one cents a ton. The production of boards, comprising straw, card, bristol, card middles, and tickets, is likewise divided among a number of States, although New York turned out twenty per cent, Connecticut fourteen per cent, and Indiana thirteen and five-tenths per cent of the total. Strawboard is the most important product, Indiana, Ohio, and Illinois, in the order named, being the leading States in its manufacture, as they are the centre of the great straw-producing section of the country. Indiana alone produced more than one-third of all the strawboard made, which was valued at twenty-six dollars and eleven cents a ton.

Under the head of "other paper products" tissue paper is the principal item, which increased fifteen thousand five hundred and nineteen tons, or fifty-four and six-tenths per cent in quantity, or forty-five per cent in value, over 1900. More than two-thirds of this paper is produced in New York, New Jersey, and Wisconsin, forty-one and two-tenths per cent of the total being credited to New York alone. Building paper, which includes roofing, asbestos, and sheathing paper is made largely in Pennsylvania, with a percentage of forty-six and seven-tenths of the total, while New Jersey produced one-third of this paper in point of value. Wall paper is included in this class, and New York made sixty-eight and two-tenths per cent of the aggregate, valued at

forty-eight dollars and thirteen cents a ton. Blotting paper, which seems of relatively little importance, is made for the most part in Virginia, and the product is valued at one hundred and twenty dollars and twenty-nine cents a ton.

The production of wood-pulp and fibre, which amounted to 1,921,768 tons, was concentrated somewhat in New York, Maine, Wisconsin, and New Hampshire, as these States made seventy-six and nine-tenths per cent of the total quantity. New York and Maine made fifty-five and three-tenths per cent, while New York alone turned out thirty-one and five-tenths per cent. Of the total quantity of wood-pulp, ground pulp amounted to 968,976 tons, or fifty and four-tenths per cent, of which New York produced thirty-nine and one-tenth per cent; sulphite fibre constituted thirty-nine and four-tenths per cent, or 756,022 tons; while soda fibre was ten and two-tenths per cent, or 196,770 tons. Pennsylvania and Maine produced fifty-four and three-tenths per cent of this pulp. The amount of wood fibre which was made to sell decreased from 1900, which, considering the great increase in the wood-pulp produced, indicates that there is a growing tendency to work up the pulp into the finished product, in the pulp-mill.

Before 1880 the paper-making materials, as the industry was conducted in this country, did not include the wood-pulps which now constitute such large proportion of them. What little was used was ground pulp, and no chemical pulp at all was made in the West. It was only twenty-five years ago that sulphite pulp, made from spruce logs, came into use, and then only in a small way. Poplar and hemlock were later used in this process, but the superior quality of that made from spruce renders this material more largely used when the timber supply is available. This has forced the largest paper-mills to the north woods in Maine, Michigan, Wisconsin, and other northern States. Although the great timber

resources of Wisconsin, as respecting spruce, are about exhausted, and supplies are drawn from Minnesota and Canada, this State in 1909 came into third place in point of production of paper, and is the largest producer in the West and Middle West. The industry here comprises seventy-five paper-mills, owned and operated by forty-five corporations, making four hundred and fifty-nine thousand tons of paper, two hundred and sixty-four thousand nine hundred tons of ground pulp, two hundred and sixteen thousand tons of sulphite pulp, or a total of nine hundred and thirty-nine thousand tons annually; and requiring three hundred thousand cords of spruce and three hundred and forty thousand cords of hemlock, or two million tons in all, for its manufacture. This has been a development of the last fifteen years.

In studying the progress of the industry it should be borne in mind that —

"there are two kinds of wood-pulp: mechanical, made by grinding the wood on a revolving stone, and chemical, made by reducing chipped wood to pulp by chemical processes. Ground, or mechanical, pulp makes brittle paper and other kinds of pulp are therefore generally used with it. The chemical fibres most used are soda and sulphite, so named from the fact that the wood is reduced by cooking in a solution of caustic soda, or of bisulphite of magnesia or of calcium. Soda fibre is soft and has other desirable qualities, but lacking strength, is usually mixed with other fibre. Sulphite is both strong and of good quality." *

The methods of preparing the wood in the United States are similar to those employed in Europe, the only difference being in the chemical treatment of the wood in the digestor. The direct, or quick, cooking method with live steam is generally used in this country, and requires twice the amount of steam, and much more sulphur and lime, than the indirect method used abroad. The indirect method, using superheated steam, produces

* Bulletin 80, Census of Manufacturing, p. 30.

a much stronger fibre, and at a less cost than the method here used.

"The recent introduction of wide, high-speed Fourdriniers is a notable feature in the progress of the paper industry. Machines, instead of being speeded to run less than 300 feet of paper a minute, are now built to make from 500 to 618 feet of news paper a minute. The width has also been gradually increased from less than 100 inches to at least 164 inches. There has been considerable discussion as to the merits of these wide, high-speed machines, the introduction of which was due to the progressiveness of a few manufacturers, who realized that by producing more paper they would have a distinct advantage over their competitors. The cost of operation is said to be much less per ton for production than for the smaller machines. Moreover the construction of the wide machines has been so perfected that loss by wear has been reduced to a minimum. The question has been raised as to the quality of the paper produced by the high-speed machines, but it is generally thought that they can produce as good a quality as the slower machines." *

Such improvements have been made in recent years in the construction and equipment of paper and wood-pulp mills, that the study of the chemistry of paper-making and a technical education and training for paper-makers is recognized as necessary to the progress of the industry. There is a paper-making school in Vienna, Austria, one in Manchester, England, and one in Germany, but the United States is still backward in this respect.

Because spruce, poplar, and hemlock are the real economic paper-making materials, and water-power is the cheapest power to grind the wood and run the ponderous paper machines, the paper-maker is in fact a natural monopolist. It could scarcely be otherwise, since the control of large timber reserves and conservation of their resources requires an immense capital, the erection and equipment of a modern paper-mill and the development of the water power to run it, entail a large outlay

* Paper Mill and W. P. News, 2, 10, 1906, p. 90.

of money, and the marketing of the product combats the keenest competition of rival producers. Before the advent of these materials, which made the modern newspaper possible, paper made from rags, straw, and some other wastes, was a very costly article, while spruce wood was sold at a trifling price, and the water-power of forest streams and lakes was unused. Within thirty years all this has changed, and an area as large as the State of Rhode Island is annually stripped of its timber, while entire forests are converted little by little into paper for newspapers and books. The so-called paper trust owns one and a half million acres of timber rights in the Province of Quebec; and the Berlin Mills also control under register rights tracts aggregating as much. But notwithstanding the enormous quantity of timber cut for wood-pulp, it represents only three per cent of the total timber cuttings for all other products of the lumber industry. Instead of being one of the greatest menaces to our forests, as has often been represented, the wood-pulp business is one of the best guarantees for their perpetuity through the enlightened policies adopted in recent times by the industry.

Up in the northern wilds of Maine, where the rivers and streams, and even the brooks float the spruce and poplar logs down to the very gangway of the mills, and at the same time furnish the water-power for their operation, the economies possible under the colossal scale of operation need no better illustration than all the various subsidiary activities: careful cutting of trees and reforestation, regulation of streams for water-power and transportation of logs, and control of dams to raise the level of tributary lakes to prevent a power-famine in dry months. Of administrative policies a leading manufacturer has been quoted:

"From the very start we make our calculations to assure permanence. Our mill needs a tremendous water supply, both for power purposes and in paper-making. Hence, we have to look

after the streams and lakes, which are also cheap thoroughfares for transporting our material. If we destroyed the forests we would lose our supply of spruce logs and ruin our water-power by making it irregular and undependable. It would mean not only 'after us the deluge,' but there would come also the drought, and that would be still worse."

It was an accurate survey of some three hundred thousand acres of forest lands and two or three years of close study of the subject that gave the paper company exact and detailed information of the timber on every acre, and a scheme for the scientific and economic management of the business.

The conservative plan from the beginning assured a perpetual timber supply, as no tree less than nine inches in diameter, breast-high from the ground, is cut. In sixteen years the spruce growth renews itself, and the ground may be cut over again, yielding nearly the same quantity of wood as before. Under the old-time, short-sighted policy of cutting all trees, small as well as large, the worthless fir balsam sprung up in its place, and vast areas of agricultural lands bordering on the forests suffered the usual penalty for the destruction of all timber. A corporation which follows economic lines in the administration of its affairs, and deals with its holdings as a permanent investment, is the Great Northern Paper Company, at Millinocket, operating the largest paper-mill in the world. It is situated about one mile above the confluence of the Millinocket River with the west branch of the Penobscot, near the point where a diversion of the waters gave a fall of one hundred and fifty feet, with a power development of 27,400 horse-power. With only the great paper-mill for dependence, the busy town of Millinocket sprang up almost under the shadow of Mount Katahdin in the forest wilderness; but its five thousand inhabitants enjoy all the benefits of a modern municipality — pure-water supply, sewerage, electric lighting, good schools, and hotels. These

advantages, as well as comfortable, modern homes for the workmen, who number nearly one thousand, were provided very largely through the far-sighted policy of the company.

The pulp-and-paper-mill covers five and a half acres, and consumes daily three hundred and thirty-eight cords of spruce and poplar wood in making three hundred tons of news paper, which is its maximum capacity. This requires something like 160,942,000 feet, board measure, of timber for a year's run of 310 days. The average yield of spruce trees as cut from the forest is about one-third of a cord of wood which, when reduced to a pulp, makes five hundred pounds of paper, an amount of the finished stock that is turned out every thirty seconds that the mill is running. The finished product fills ten standard railway cars every work-day for transportation to market, while the yearly output of ninety-three thousand tons requires three thousand one hundred cars which would make a train twenty and a half miles long. The power needed to make this quantity of paper from the logs is thirty-seven thousand five hundred horse-power; and since twenty-seven thousand four hundred horse-power is derived from turbine water-wheels, there remain ten thousand one hundred horse-power to be supplied by steam. This latter power is used principally for "cooking" purposes, and requires in a year fifty thousand tons of Pocahontas coal, which would fill 1,667 standard railway gondolas, making a train more than twelve miles long. In addition to the regular equipment of grinders, there is an extra battery for use in times of high water, when the water-power is above the normal, to turn out vast quantities of pulp to meet the needs of the paper end of the mill, in a season of low water, when the loss of power reduces the output of the regular grinders. There are some seasons when ten thousand tons of pulp-sheets are stacked in the yard ready for the paper-mill.

From these figures it will be seen that great energy

is required to convert logs into paper, and the important economic factor in the process is the utilization of cheap water-power. Green spruce-logs average about thirty-two hundred pounds weight to the cord; and as one and one-eighth cords are used to make a ton of news paper, the raw material weighs thirty-six hundred pounds. To make three hundred tons of pulp in a work-day of ten hours requires a total energy of thirty thousand horse-power, which is equivalent to one hundred horse-power-days for every ton of pulp produced, or one thousand horse-power-hours. Although a large proportion of this energy is expended in grinding the wood, there is much work done in evaporating the great amount of moisture therein, in the processes of manufacture. The amount of heat required for the evaporation of twelve hundred pounds of water in making one ton of paper is enormous, since each pound absorbs 966 heat-units in passing to vapor. The daily output of the mill necessitates the evaporation of three hundred and sixty thousand pounds of water, or thirty-six thousand pounds every hour; and that is accomplished by steam at low pressure (ten pounds maximum) or just sufficient to raise the temperature of one pound of water in the paper stock to two hundred and twelve degrees Fahrenheit, and then evaporate it at atmospheric pressure.

But in practice, the steam entering the dryers does not do more than one-half its useful work in evaporating water from paper stock, hence for effective evaporation an amount of steam sufficient for seven hundred and twenty thousand pounds of water a day, or seventy-two thousand pounds an hour, must be drawn from the boilers. As boiler horse-power is rated at thirty pounds of water evaporated at two hundred and twelve degrees Fahrenheit an hour, it is clear that a battery of twenty-four hundred horse-power is required to do this amount of work. The steam engines throughout the mill exhaust into the heating system of the paper machines, and

the exhaust steam has the same value, pound for pound, as that taken direct from the boilers through reducing valves. Other power requirements of steam for driving engines and pumps and auxiliary machinery, aggregate seven thousand seven hundred horse-power, for the full capacity of the mill. With an invested capital of two-and-a-half million dollars and a production of ninety-three thousand tons annually, the investment is twenty-six dollars and eighty-eight cents for every ton of the output.

In the preliminary operations of the wood-pulp mill, the spruce or poplar logs are floated from the river into the mill-pond alongside, and thence conveyed to the cutting end, where in a large room they are sawed into two-foot lengths, and the bark is removed. All pieces over ten inches in diameter are split by hand, but they average about eight inches in size, so that an average of one hundred and forty-four make one cord of wood. As three hundred and thirty-eight cords are cut daily, the number of pieces is 48,672, and for a year 15,088,320 pieces. If these were laid end to end they would extend for 5,712 miles, or nearly one-fourth the distance around the globe. About one-third of the short, clean logs are worked up into sulphite stock, and to this end they go to machines which break them up into small chips. The bulk of the logs, however, being intended for ground pulp, go to the grinding-mill, where they are reduced to a pulp. The object of mixing sulphite stock with ground pulp is to hold the latter together in the finished product, much as rag stock does in some grades of book and writing papers.

In making sulphite stock the chips pass to revolving cylindrical screens in which all grit is removed, and then go to the digestors by means of mechanical conveyors. The digestors are large cylindrical steel tanks lined with brick, the interstices between which are filled with an acid-resisting substance or cement. Therein the chips

are "cooked" in a solution of sulphuric acid, for ten hours by steam at one hundred pounds pressure. The mixture is then drawn off to concrete pits and the acid washed out, when it passes to storage tanks. From there it is pumped, as needed, to screens which remove all coarse particles, and is then distributed in a thick layer over felt, in machines which by heavy pressure squeeze out a large portion of the water. It comes out a homogeneous fibrous material in the form of heavy sheets, of a pinkish color.

The larger portion of the short logs, amounting to two hundred and twenty-five cords daily, are subjected to a very different treatment. In the grinding-room are row upon row of special hard grinding stones revolving on long horizontal shafts, and completely enclosed by heavy, cast-iron casings. From the upper periphery of each casing three cylinders nearly three feet long extend in radical directions like the spokes from the hub of a wheel. The logs are placed within these cylinders, which are ten inches in inside diameter, and their ends are forced against the swiftly revolving stone by the heavy pressure of hydraulic rams, and quickly ground to a fine pulp. The main battery consists of forty-eight grinders, with one hundred and forty-four logs, or one cord of wood, being ground up continuously. Since two hundred and twenty-five cords of wood are reduced in a work-day of ten hours, or six hundred minutes, a cord is ground out every two minutes and forty seconds of the time. Each cylinder grinds two hundred and twenty-five short logs in a day, or forty-five linear feet an hour. A great amount of power is used in this work, each grinder requiring three hundred and twenty-five horse-power, or a total of fifteen thousand six hundred for the main battery. Each of the four long shafts mounts twelve of the grinding-stones, and is directly connected to the extended main shaft of a turbine water-wheel developing thirty-nine hundred

horse-power. It is evident that each of the two hundred tons of pulp produced in a day requires the expenditure of energy equivalent to seventy-eight horse-power-days, or seven hundred and eighty horse-power-hours. In addition to this several thousand horse-power are used to operate the pumps which furnish the heavy pressure to the hydraulic rams, and also to operate the conveyors.

The pulp from the grinders is first thoroughly mixed with pure, sparkling water, and drawn into a series of wooden channels having little dams which catch the grit and particles of unground wood, as the stuff passes through. The refuse is removed by flushing at intervals. The fluid pulp then passes over two sets of screens, the first of which catches slivers, and the other bits of wood and grit, and on to machines which reduce the high fluid to a thickened mass; then it is run off to concrete storage-tanks. At this stage the sulphite stock is mixed with the ground stock in beating-machines, and the resultant mass reduced to a very smooth pulp. In this process the sheets of sulphite stock are torn up and rendered fluid with some "white water," a product of ground pulp, and thoroughly mixed with the latter in an elliptical-shaped tank about ten feet long and four and a half feet wide. By means of a broad wheel, having a large number of sharp teeth or ridges on its surface, revolving against the ridged surface of a dam, or "fall-back," the stuff is rasped and drawn violently through, by the constant current formed by its revolution, and "broken in," as technically expressed. The fluid mixture then passes to "chests" in which the beating process is continued until it becomes fine and smooth, when it is ready to be made into paper. It passes, meanwhile, to machine chests where it is constantly stirred and agitated to prevent settling, until drawn to the paper machines in a highly fluid or milk-like state.

In converting this pulp stock into paper the same general principles are employed as in the early machines

improved by Bramah and Fourdrinier, although the paper machines here used are of such size and capacity as to exceed the most extravagant dreams of the inventors. The object is simply to cause an even and uniform supply of the pulp to be taken up on an endless wire-gauze apron, or on wire-covered cylinders, which drain off the bulk of the water, as the wire mould did in the old hand process; to deliver the fibrous material on an endless sheet of felt passed around and between large couching rolls, which remove more water; then to run the sheet by itself around hot rolls, which dry it into firm paper; and finally, to pass it around other rolls under great pressure, which give the desired surface. The great modern machines are 177 feet in length, 18 feet in width, and 16 feet in height, and turn out the finished paper in a few minutes from the time the pulp leaves the stuff chest, at a rate of 500 feet a minute.

In the interesting process the pulp partly fills a long, wide vat, which forms the base of the front end of the machine, so that five cylinders, fourteen feet long and three feet in diameter, hung near the top of the vat, are about two-thirds submerged. These cylinders are covered with fine wire cloth, and revolve slowly through the pulpy mass, taking up on their surface a thin layer of it. As the layer of pulp is brought to the top of the cylinder, a large proportion of the water runs off through the fine meshes of the surface, and is discharged from within through the hollow shaft. Along the opposite side of the cylinder, and pressed down to it by rolls, runs an endless blanket of felt that catches the fibrous pulp and carries it up and over a series of rolls, which by pressure squeeze out the remainder of the surplus water, and compress it into a thin, continuous sheet. After passing over steam-heated rolls, this sheet is strong enough to sustain itself. The speed of the rolls and the travelling blanket is calculated and adjusted

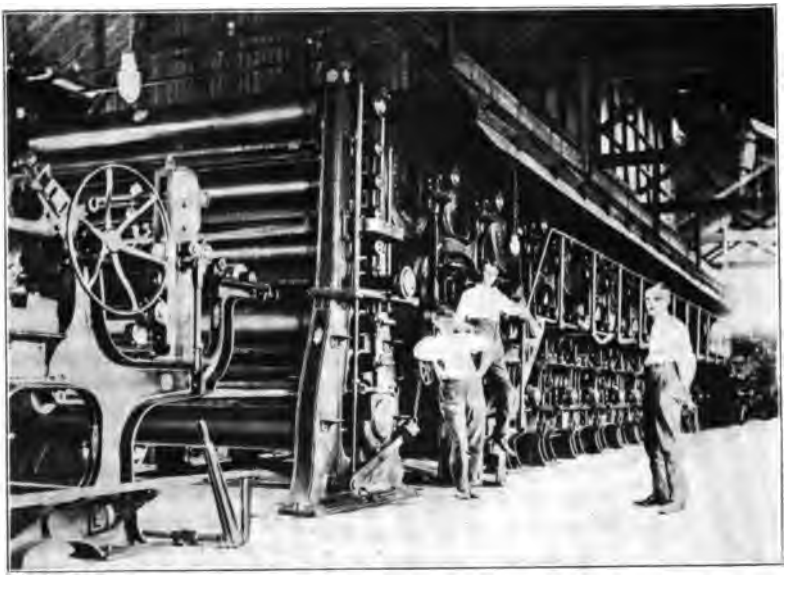
UNIV. OF CALIFORNIA

"WET" MACHINE

CALENDERS AND CUTTING MACHINE

THE "HESSERS"

[See page 123]



END OF LONG PAPER MACHINE

to a nicety, so as to prevent a strain upon the very tender web of paper.

The endless sheet of paper, now trusted to itself, passes to the first set of drying-cylinders, which are of large size and filled with steam. Around these it goes drying gradually with its every turn until, received between two smoothing rolls, the marks of the wire and felt are removed. The second series of drying-cylinders complete the process of eliminating the moisture, when the dry, firm paper passes to the calenders, which are polished rolls adjusted to give a hard surface for the desired finish. The paper is then wound off on long spools, to rolls about three feet in diameter, covered with a wrapper, and conveyed to the cars for shipment. When making newspaper sheets the endless web is run through a cutting machine adjusted to the desired size, which cuts and piles it in ream lots ready to be wrapped.

A single sheet of good news stock is three-thousandths of an inch thick, so that four thousand of them pressed together are needed to make a pile one foot in thickness. The usual four-page newspaper sheet is six square feet in size, hence six hundred and sixty-six of these make one cubic foot, which weighs twenty-five pounds. From these figures a simple calculation reveals the astonishing amount of paper used by great city dailies. Taking the Sunday issue of a leading New York paper for instance, which, with its fifteen to eighteen sheets run 2,960 complete copies to the short ton, the total quantity of stock used for the half-million copies, amounts to 168 tons, which would fill five standard railway cars. The daily issues consume much less, but the fact is evident that the entire output of the great paper-mill at Millinocket, running 310 days in the year, is hardly sufficient to meet the steady demands of three of the largest metropolitan papers.

Although the processes of making paper from the

various materials commonly used are very similar, the methods of working up rags into pulp are instructive, and will be found interesting. The earlier paper-makers, in their crude way, took cut rags and piled them moist in cellars or vats to rot. In six to twenty days the vegetable gluten had fermented or putrefied, when the water was evaporated by heat, chemicals, and power, leaving a "puree" or smooth soup of fibre. This was then bleached and further disintegrated by beating with mallets, or by stampers moved by water or wind power. It was then made into paper by the hand process already described. In strong contrast to the primitive methods are the present means employed by the Parsons Paper Company, in their mill at Holyoke, Mass., in making the famous Scotch linen ledger paper. Holyoke is the "Paper City" of New England, within whose borders there is made the greater portion of the fine papers made in this country. The water used by this company for power purposes to the amount of one thousand horse-power would cover, it is said, a hundred acre field ten feet deep every twenty-four hours. Besides this, five million gallons of spring and filtered water are used in the same time in the processes of manufacture.

As received in compressed bales, the rags are first put into a duster, a machine which, with a revolving motion, shakes and blows out the dust and fine particles, and are then carefully sorted over wire screens to remove foreign substances, such as pins, wires, hooks and eyes, buttons, and rubber. This is a most important work, since if not taken out, the hard matter is ground up and distributed through the pulp, impairing the quality of the paper. The rags are cut into small pieces by drawing them across a knife held in an upright position on a table; but trimmings from shirt factories are run through a cutting-machine, as they are too small to be cut by hand. They then go into an iron boiler in which there is a solution of lime and other chemicals, and are

cooked with steam for several hours. After thorough washing in a machine quite similar to that used in the "beating in" process of wood-pulp, the fresh water is shut off, the roll is lowered, and the fibres are "brushed" or reduced to a pulp. Chlorine is then added to bleach the stock, and after a time it is run into beating-engines and made into a fine, smooth pulp. After thorough mixing with the purest spring water, it is ready for the paper machine which, except in minor particulars, is the same as those used in making news paper, although of smaller size. The distinctive water-mark is impressed in the still wet paper by a wire roll, upon which is sewed the lettering or design. When dry the paper is sized by passing it through a tub containing animal glue. This fills the pores of the sheet and prevents the spreading of the ink. When thoroughly dried in the lofts by hanging over poles and by the aid of steam heat, the surface is smoothed for the requirements of the trade.

In making other kinds of paper, including colored papers, the treatment in various stages differs in some particulars. For instance, the so-called "wove" papers are made by using a fine, closely woven wire-screen like cloth, in the first draining process; on the other hand the "laid" papers require the use of a screen having straight wires crossed an inch or so apart by stouter ones. The roll which impresses the water-mark usually follows, and leaves the outlines of the design thinner than the rest of the paper, thus showing the mark plainly when held to the light. In the case of colored papers the foreign matter may be introduced into the pulp, when it is, of course, incorporated in the body of the paper, or it may be mixed with the size and applied to the surface. There have been numerous ingenious devices evolved for giving paper a marbled or beautiful iridescent appearance; papers of this kind have a limited use for specific purposes.

Peat, that black, spongy, fibrous substance from bogs, which from the early ages has been one of the world's principal fuel materials, and which scientists say is but coal in the making, has recently been turned into other channels of successful manufacture, and is the last resource in the long list of paper-making materials. The peat bog furnishes a good substitute for wood in making wrapping paper and boxboard, and a superior quality of these papers is now being produced on a commercial scale. Peat is a vegetable substance deposited by the slow accumulation of thousands of years, the peculiar fibrous quality being due to the decomposition of plants, moss, ferns, and roots. It is the pure fibre obtained from peat that gives it value in paper-making. All varieties of peat, however, do not contain fibrous matter in sufficient quantity to be of value. Well-decomposed peats, which are usually of a black color and somewhat spongy and waxy, contain but few fibres, while those of a much later period of brownish color and rather loose in texture, are the kinds which produce the material for paper-making.

The quantity of peat in the world is enormous. It exists in all the countries of Northern Europe, and in Siberia; there is also much of it of value in smaller bogs in various parts of the United States and Canada. Deposits from ten to fifty feet in depth and many miles in extent are not unusual. A productive peat bog usually shows a top layer of rank grass and living plants, a few feet below this is found a thick deposit of partly-decayed plants and vegetable growth, containing well-defined fibres of use to the paper-maker, while toward the bottom a mat of black, spongy peat, is encountered, in which fibrous matter may be totally absent. Such bogs liñe only in temperate, cold, and humid climates. Toward the regions of higher temperatures all vegetable matter is more rapidly decomposed; and in the tropical zone the putrefaction of animal and vegetable matter

is so rapid that the formation of the substance and structure of peat is impossible. In the passage of time the spongy deposit in all swamps grows deeper, the slow process of oxidation taking place with the evolution of hydrogen, oxygen, and some nitrogen. It takes the form of carbon dioxide, marsh gas, and water, the deeper portions becoming more compact and spongy, while the covering of water excludes air.

The first attempt to make paper from peat was made some years ago in Ireland. A paper-mill was erected at Culbridge, and was operated by water-power. The patriotic people of the countryside put forth their best efforts to place the new commodity on the market, and it was enthusiastically announced and heralded far and wide that "making paper from the soil of old Ireland is an established industry." But many difficulties beset the early experimenters. The peats they had to work with contained much soil and dirt and too little fibrous matter, and the process of removing the foreign substances necessitated the use of large amounts of soda in the boiling-vats. They had to combine rags, ropes, or hemp with the peat in making a kind of paper suitable for wrapping merchandise, and it was less desirable because of its dark color, as they had no bleaching agents to give the peat-pulp a satisfactory shade. These serious drawbacks to the economical use of peat, at least for paper intended for general use, prevented the development of the industry.

Another enterprise of this kind on a larger scale was later begun in Sweden, where a company, capitalized at one million dollars, made extensive purchases of peat bogs and erected a number of paper-mills for the manufacture of wrapping paper and pasteboard. The money for the undertaking was obtained largely from London, but the processes by which the vegetable fibre of the peat was converted into paper were covered by an American patent protected in foreign countries. It remained,

however, for American tests to satisfy capitalists that peat-made paper would command a price that would make its manufacture profitable. It was demonstrated that a ton of paper worth from twenty-five to thirty dollars could be made from peat at a total cost of a little more than eight dollars, while the usual grade of straw-board costs nearly twenty dollars. This low cost is due primarily to the cheapness of the raw material, and the ease with which it is obtained, but it is also due to the simple and quick process by which it is turned into marketable board. The entire operations, from the peat in the bog to the finished product, cut, wrapped in bundles, and loaded in cars for shipment, are all accomplished in two hours.

The first "peat to paper in two hours" business was established by the Pilgrim Paper Company, near Capac, Michigan, at their paper-mill, which was erected and put in operation in 1906. The buildings are located on the eastern edge of an immense bog, in Lapeer County, and from the very start the enterprise has been a complete success. Passing close by is the main double-tracked line of the Grand Trunk Railway, which, by convenient switching tracks to the mill, affords adequate shipping facilities. At the rear of the annex a long, wide shed extends out over the bog for about three hundred yards, where laborers dig up the heavy, damp peat and throw it into dump cars. These cars, when filled, are drawn through the shed on narrow-gauged trams into the mill. There are several tracks with convenient cross-overs, and the line is operated by electric mine motors.

In the pulp-mill the cars dump their loads into peculiar but interesting machines called "hessers," which are made only in Austria. The operation of these machines discloses a most novel process in the preparation of the tough lumps of peat for the paper-mill. The large round bed of the machine, which is eighteen

feet in diameter, and on which the peat is dumped, revolves slowly while the mass is being broken up and kneaded into a soft and pasty consistency. This is accomplished by ten huge arms fitted with claws and hammers, which revolve rapidly, at regular intervals around the machine, and with water added, reduce the roots and moss and decayed wood to a soft mushy pulp.

The stuff is then taken out and dumped into a "breaker," which is simply an elliptical iron tank similar to those used in the wood-pulp process, and provided with a toothed wheel which revolves horizontally. Much water is here added, some scrap paper is dumped in, and, after a time the mass is thoroughly macerated and rasped, the fibre becoming a thin black pulp. In the liquid state it is allowed to flow into one of two "stuff chests." These are circular concrete tanks imbedded below the floor, and are fourteen feet in diameter by twelve feet deep. To purify the dark fibrous liquid, two "jordan engines" draw off a certain amount; and then, by a mixing process, and by passing it over five screens of varying sizes of mesh, which effectually remove small stones, dirt, and stringy matter, the mass becomes a clean black pulp. In all these processes water is an all-important factor; and an abundant supply is obtained from Artesian wells. The water is forced from below into an elevated tank, by means of compressed air, through a small pipe inside the well-tubing; from the tank it flows to the various machines in the mill.

The process of preparing the fibre and purifying it being accomplished, it is ready for the actual operation of making into boxboard, which is in no way different from that used for working up wood-pulp. As the peat boxboard leaves the big machine, however, it is put through a calender, which, through the medium of heavy pressure and great heat, gives it the desired finish. It then passes to the cutting-machine directly at the end of the calender, which cuts the endless sheet of paper or boxboard

into regular sheets of any size and shape, and delivers it in piles, stacked in precise order and counted. It is then tied in bundles, weighed, and loaded into cars for shipment.

The finished product is in several ways superior to the cardboard made from straw or wood-pulp. The passing of the peat pulp over the hot rolls in the process of manufacture brings to the surface of the paper the natural oil of the peat, and makes the surface of the finished product water-proof and antiseptic. Besides this advantage it is lacking in the odor which strawboard or wood-pulp paper possesses, and is extremely tough. The plant of the Pilgrim Paper Company operates twenty-four hours a day, six days a week, and turns out thirty tons of the boxboard every work-day. The product is used principally for cartons by makers of breakfast foods, and for this purpose it is unexcelled. It is also valuable for making boxes and bags for storing furs and woollen articles, as it is never attacked by moths. Although the material is so easily obtained at low cost, and the process of converting it into paper entails less expense than for other substances, it is not expected that peat will take the place of wood-pulp for making news paper or white papers of better grade. It helps, however, to meet the demand for coarser grades of paper, and thus relieves the pressure upon the timber supplies of the country.

¶ Aside from the common uses of paper in the publishing world, the commercial world, and in the arts and sciences, there are other useful purposes to which paper, in one form or other, can be put, and in which it is of economic value. Paper treated with paraffin becomes impermeable to water, with but little added to its weight, and, besides being a suitable and convenient wrapper for food stuffs, is of great value in making bottles for the marketing of milk, medicinal waters, beer, and other liquids. With only one-half the weight of

glass, paper bottles will withstand a pressure of two hundred pounds before collapsing. After being used the bottles are thrown away, as they cost only half a cent each; and their hygienic value over the doubtfully sterilized glass bottle is perfectly plain. One bottle plant alone makes two hundred thousand antiseptic paraffin-paper bottles a day. Large quantities of filtering-paper, used by chemists and the drug trade, and bromide-paper in photographic work, are annually made, as also paper pencils and *papier-maché* goods. In electric lighting a certain kind of compressed paper, chemically prepared, is a valuable factor for insulating purposes on a large scale. Paper has also been used for making hollow telegraph poles, but for this purpose it has not proved of great value.

It may be somewhat of a mystery to the lay mind how railway car-wheels can be made of compressed paper to withstand the strain and wear and vibration better than all-steel wheels. But paper wheels have long since passed the period of novelty, and are made in a great variety of shapes and sizes for numerous purposes. It was in 1869 that Richard N. Allen, a locomotive engineer, made the first paper car-wheels, which were tested for six months in the trucks of a wood car running on the Central Vermont Railway. Two years later the Pullman Palace Car Company gave the first order for one hundred wheels, and in actual tests some of these wheels travelled from two hundred and fifty to three hundred thousand miles. In 1881 the Allen Paper Car Wheel Company turned out thirteen thousand paper wheels in their shops at Hudson, New York, and Pullman, Illinois. Since that time this kind of wheel has come into universal use for first-class coach trucks.

Only the body of the wheel is made of paper, the tire, hub, and axle being made of cast-steel. Twelve sheets of rye-straw board, or thick paper, are cut in circular pieces from twenty-two to forty inches in diameter,

pasted together, and subjected to a pressure of five hundred tons by a hydraulic press, for two hours. After seasoning for six or seven days in a drying loft heated to one hundred and twenty degrees Fahrenheit, a number of the discs are again pasted and pressed together and dried, as before. The thicker discs thus made are then pasted together and given the same treatment, the result being a circular block from four and a half to five and a half inches thick, and of solidity, density, and weight more nearly resembling metal than fibre. After being turned off in a lathe to a diameter slightly greater than the inside diameter of the steel tire, the wheel is forced into the tire by hydraulic pressure; the hub, which has already been turned out to fit the axle, is pressed in, and the circular protecting plates of wrought iron are bolted and riveted in place over the outside. The axle hole is then bored, and the wheel is ready for the axle, upon which it is forced to true gauge by hydraulic pressure, and is afterwards placed in the truck.

By the spinning and squeezing process of drawing wood-pulp out into the thinnest sheets imaginable, the paper does not lose its toughness, and may thus be made into delicate paper napkins and table-cloths, and printed with fancy borders and figured patterns. Some of these papers have been made almost as tough as linen respecting their resistance to tearing, but moisture destroys this desirable quality. Paper yarns have been a subject of experiment for a number of years, and fabrics woven from such material are made into various articles of wear. Underclothing made from woven or knit paper cloth is declared by modern authorities to be far more hygienic than garments so woven that the exchange of the toxic emanations of the body with the outer air is very low. Furthermore, the paper-yarn woven cloth is cheaper; it can be readily laundered, the use of soap only making it softer. Paper vests made of pulp-sheet paper chemically treated, and not woven

yarn garments, are light weight and pliable; they do not make a rustling sound, but exclude the cold and wind to a remarkable degree.

The process of preparing the new thread and yarn, called "zylolin," is held in absolute secrecy, the inventor, Emil Claviez, a native of Saxony, having arrived at the practical and highly satisfactory results after years of painstaking study and experiment. It may be loosely or tightly spun, of any thickness, and woven into numerous fabrics. As these fabrics have been tested repeatedly and made into all sorts of garments and shoes and hats, which have given good service, there remains no doubt that zylolin will some day be regarded a staple article of trade. Being primarily a thread, having nothing whatever of the nature of papier-maché or paper in sheets or blocks, it may be employed in any of the common types of looms used in the textile industry, although some slight alterations may be desirable for its readier manipulation. A carpet loom of any type can be used with the new yarn in making rugs, mats, and carpets, which may be of any desired thickness and woven in beautiful designs. There is an elasticity to the tread in such floor-coverings; they do not retain dust, and may be beaten or washed without injury. Although not possessing the richness of Oriental rugs, the rugs and mats made of zylolin are very well suited to summer homes and to veranda use.

The thread of zylolin is not brittle or of hard surface, and neither shrinks nor stretches to an appreciable extent. It possesses certain resilient qualities, and is not readily crushed like paper. When bleached to a snowy whiteness it has the appearance of cotton, and becomes a ready substitute for cotton, linen, jute, or even silk. It combines the good qualities of cotton and linen at one-third the price of the former material, and one-tenth that of the other. In 1906 seven million towels made of zylolin were sold at a wholesale price of twenty-four

cents a dozen, few of the users noticing the difference in the material. The cost of a good woven fabric suitable for a three-piece suit of clothes is only one dollar, and the kind used for overalls and jackets costs only one-half that commonly used. It is also suitable for wall hangings and furniture coverings, and has been made into jute sacking by using one thread of jute to two threads of the paper material. It is said that ninety-five per cent of the material used in making the thread is cellulose, and five per cent cotton, which is subjected to a novel treatment before spinning. Zylolin may be dyed in the most delicate shades, the range of colors outmatching that to which cotton, linen, or silks are susceptible, and even the richest hues are not affected by strong light.

Waterproofing of paper — to open up still other novel uses for it — has had considerable attention by chemists and paper-makers, and paper sheets have been glued to cloth to render the latter impervious to moisture. Fireproofing of paper has been accomplished by injecting non-inflammable chemicals into the wood-pulp when soft and pliable, thus neutralizing the inflammable material of the wood. When the pulp is hardened by hydraulic pressure, the chemicals remain in the wood (or compressed paper, as it has become), and it is found useful for wainscoting, dadoes, ceilings, and mouldings, taking the place of wood for finishing.

V

RUBBER

FROM MILK OF THE TREE, VINE, AND PLANT TO FINISHED PRODUCTS. PROPERTIES, DISCOVERY, SOURCES, PRODUCTION, AND VARIED USES OF CAOUTCHOUC.

HARDSHIPS ENDURED BY THE PRODUCERS OF CAOUTCHOUC — ITS PROPERTIES — CHEMICAL COMPOSITION — DISCOVERY — REGIONS WHENCE IT COMES — COLLECTING THE JUICE — THE CURING PROCESS — THE GUAYULE PLANT — BEGINNING OF THE WATERPROOF CLOTHING INDUSTRY — PRINCIPAL DISTRIBUTING MARKETS — CULTURE OF RUBBER TREES — MANUFACTURE — LARGEST RUBBER-MANUFACTURING COMPANY IN THE WORLD — STEPS IN THE PROCESS OF MANUFACTURE — THE MAKING OF GARDEN HOSE — STEAM PACKINGS — THE WORKING UP OF SHODDY.

THE peculiar substance known to science as *caoutchouc*, but in the industrial arts as *rubber*, is one of the products of the wonderful chemistry of nature, and its extraction and manufacture are features of our commercial activity that combine elements of unusual interest. It is probably the most valuable, and certainly commands the highest price in the open market, of all the raw materials which enter into so many and varied articles of universal use. This is largely due to the fact that rubber is a product of savage rather than of civilized industry; and there is no other substance or article of trade that is a more important contribution of barbarous races to our industrial civilization. Being a product only of the tropical regions of the earth, its extraction from the trees and vines of the jungle and swamps or the plants of the desert is attended with many dangers and hardships. Only the natives of the torrid zone can safely enter the depths of the forest and successfully carry on the operations of

cutting the bark, collecting the milky juice, and drying out the caoutchouc. Even they succumb to the deadly vapors of the marshy jungle with a persistency that indicates the loss of one life for every ton of rubber taken out. The average life of the natives engaged in such work, after entering the jungle, is only three years.

Crude rubber is soft and plastic, but its most remarkable property is its elasticity. When cold and quiescent it is hard and stubborn almost to rigidity, but heat at moderate temperature softens it. If a slip of the substance be softened by immersion in hot water, it may be extended to seven or eight times its length, and will again contract to very near its original dimensions. Its imperviousness to water and air is also of great value in the commercial arts, and to this, as well as to its other properties, is due its employment in the manufacture of pneumatic tires, hose, belting, packings, tiling, clothing, fruit-jar rings, and many other articles of daily use. In the manufacture of elastic fabrics, such as cloth, cord, tape, and braces, one general rule is employed, namely, to reduce the rubber to threads.

In the early days of the industry, fifty or sixty years ago, the filature was done by means of steel edges acting either on the bottle caoutchouc, compressed in a mould on a solid cake, or by cutting it when stretched on a mandrel of wood set in rapid revolution. In the latter process water was used on the cutting blades to prevent collusion that would impede the operation. Upwards of five thousand yards of fine rubber thread have thus been produced from one pound of the material. The natives of the Amazon Valley have long made crude waterproof boots of caoutchouc by infusing coarse cloth with the milky juice of the Hevea. This liquid, if kept in well-corked bottles, may be preserved for a time without much change; but, however perfectly the air is excluded, it will ultimately solidify. If exposed to the air in thin films it soon dries, losing from one-third to one-

half its weight, and leaving caoutchouc of the usual appearance. Heat coagulates the juice and separates the caoutchouc; and alcohol and acids produce the same effect.

In collecting the milky juice, or latex, of the rubber tree and extracting the precious substance in various forms of crude rubber, the natives use the most primitive means. They wound the bark of many trees by means of a small knife; they collect the latex in small cups of earthenware, and they dry it out by slow and laborious methods. The latex is applied in successive coats to the surface of clay models of bottles, and it is dried each time over slow fires, the smoke of which gives it a dark color. While it is still soft, various lines are drawn upon it with a blunt tool, and these are permanently impressed. When the whole is dry the clay is crushed and shaken out of the bottle or other forms. The returns to the natives for their labor are more than commensurate for the unskilled work of savages and the dangers encountered. As noted in the Colonial Report on Lagos, 1905:

"With startling suddenness the easy-going native awoke to the fact that wealth abounded in the forest about him, and learned for the first time that, in sitting under his own fig tree, he had been unconsciously reposing in the shade of the family bank."

In producing crude rubber to-day the chief problem is of labor on one hand and of pushing farther and farther into almost impenetrable forests on the other. The mortality persists in diabolical exactness to the number of tons of rubber produced; and it has been said that the hardships of life in the depths of the jungle are greater than the inhuman treatment of the slaves in the United States, or of the laborers in the coffee regions of Brazil. The greed of man, in the production of crude rubber probably holds more wretched savages in abject slavery, than are enslaved in any other field of the world's activity.

In the realm of chemistry rubber is a carbohydrate, and in a state of purity is a nearly colorless colloid, with a specific gravity of 92 at a temperature of seventeen degrees Centigrade. It is a product of vegetable latex, the quantitative composition of which is indicated by the symbol C_{10} H_{16}. Analysis of Hevea latex shows that it contains thirty-two per cent of rubber, twelve per cent of proteid and mineral matter, and fifty per cent of water. The quantity of resin proteids and ash in the latex depends very much on the chemistry of the soil, and to a large extent determines the grade of rubber as respects elasticity, tensile strength and durability. The finest grade of Para rubber contains less than one and one-half per cent of resinous extract, while the low grades of African flake often contain as much as sixty per cent. In treating the latex, the water is first dried out, the rubber existing in it in the form of globules held in suspension, and lighter than water. Coagulation is a process of fermentation, and in the process of drying out of the containing liquid the resinous matter becomes a part and parcel of the rubber. The dry rubber may contain as much as four per cent of proteids or albuminous matter, but they only add to the complex nature of the product, and affect its value.

Certain resinous gums of the caoutchouc species were known to civilization several centuries ago. At an early period in American history, balls made of the *gum of a tree,* but lighter and bounding better than the wind-balls of Castile, were known as novelties. They were mentioned by Herrera in his narrative of the second voyage of Columbus, as giving amusement to the natives of Hayti. The substance must have been known in Mexico as early as 1615, as a book published in Madrid by Juan de Torquemada mentioned a tree which yielded it. The mode of collecting the gum, as well as of its use in making shoes, and the practice of the Spaniards of waxing their canvas cloaks with it to make

them resist water, is quite fully described. It was introduced into Europe in the early part of the eighteenth century and shown in the museums, but was regarded merely as a natural product having curious and interesting properties. Its origin, however, was unknown, and not until 1736 did La Condamine determine its true character and source. He had been sent by the French government to Peru to measure an arc of the meridian, and in his travels discovered that rubber was the inspissated juice of the bark of certain trees native to the forests along the Amazon and Orinoco rivers. The trees were called by the natives Hhve; and La Condamine sent specimens of the substance, which resembled black resinous gum, to the French Academy. The Hevea is one of the species which produce the Para rubber of commerce.

Clouth quotes La Condamine as saying:

"When the bark is slightly cut a white milk-like fluid runs out, which hardens in the open air and becomes black. The natives make lights of it, which burn without a wick and are very bright. . . . In the province of Quinto linen material is covered with resin, and used as oilcloth at home. . . . The same tree grows on the banks of the Amazon and the Mainas call the resinous fluid 'Cachuchu.' . . . They make shoes of it, which are waterproof, and when smoked they have the appearance of leather. They also make pear-shaped bottles, on the necks of which they fasten wooden tubes. Pressure on the bottle sends the liquid squirting out of the tube, so they resemble syringes."

It was this fact that gave a specific name to the rubber industry in Brazil, where it is called "seringua," the forest of rubber trees "seringal," and the gatherer is "seringuero." Although the sticky material was used by the natives for waterproofing purposes by means of the crude methods of savage life, it was not until 1770 that a clean and nearly pure rubber was introduced into Europe. In that year Priestley discovered that it was good for rubbing

out pencil marks, and it has since been known as "India Rubber."

Since the time of La Condamine from three hundred to four hundred trees, shrubs, herbs, and vines have been found, in the zone lying between the tropics of Cancer and Capricorn, which might contribute to the world's supply of rubber. They all yield to a greater or less extent a milky latex having in some degree the properties of caoutchouc, namely, resinousness, elasticity, adhesiveness under normal temperature, and impermeability to water. During this period rubber has worked something of a revolution in the industrial arts; and, as it has been so great a factor in promoting the manufacturing and commercial interests, it must be regarded as an almost indispensable product in the material progress of the world.

The increasing use of articles in which rubber is the basic material, and the consequent large demand for the crude substance, make the business of its production one of the most important enterprises of modern commerce. Its employment in various branches of manufacture reaches a greater volume each year, and its price is constantly rising. For half a century after the beginning of the industry the world's supply came from the Para district, but as the needs increased and prices advanced, the entire Amazon Valley and other fertile regions of South America were ransacked for additional supplies. Sources of supply were discovered and exploited in Africa, Asia, and Mexico, and later the cultivation of rubber trees was undertaken in Ceylon and the Straits Settlements. Notwithstanding the great expansion of the industry within the last twenty years, the price of crude rubber has advanced from twenty-five cents a pound to two dollars or more a pound for the best grade.

The present great sources of supply are the Amazon Valley and that of the Congo, but it is predicted that the future important supplies will be the cultivated crops

of Ceylon, the Straits Settlements, and Central America. The Hevea is native to the Amazon Valley, the Castilloa to the South American uplands and that of Mexico and some parts of Central America, while the Manihot belongs to Ceara, the Hancorina to Pernambuco, and the Maranaham and Bahia to various parts of South America. The African yield is largely from vines, of which the Landolphia is the chief source. In Asia it is the Ficus, or fig-like plant, which resembles the "rubber plant" often shown in green houses. The leaves, however, differ materially from those of the Hevea and Landolphia.

The best grades of rubber come from the Valley of the Amazon, which embraces the rubber forests in Brazil, Bolivia, and Peru. In the basins of the tributary rivers Beni, Madre de Dios, Purus, Yarari, Ucayali, and others, there have been found numerous varieties of rubber trees, including not only the Hevea but the Castilloa and other well-known kinds. Only a small portion of the vast forests has yet been worked because of lack of communication with the interior. The natives follow the watercourses and tap only the trees on or very near the banks, and in some places they make a practice of cutting down the trees, instead of merely wounding the bark. On account of the higher price obtained, the product is exported from the Brazilian ports, the principal one of which is the city of Para, from which was derived the name "Para Rubber." It reaches market in the form of "biscuits," the uniform excellence of which is generally attributed to the natives' method of gathering and curing it. The product of the Peruvian forests, of a lower grade than "Para," is known as "Caucho," while that of the Atlantic States south of Para, is exported under the names "Mangabeira," "Pernambuco," and "Ceara." North of Brazil the grades produced in Venezuela, Colombia, Ecuador, Nicaragua, and Mexico, are known as "Centrals."

The forest giants of the Amazon rise straight and clear fifty to sixty feet to the first branches, and are topped with a profusion of deep foliage. The leaves of the rubber-tree are three-lobed, six or seven inches long, of a dark-green color, and are not unlike those of the European ash. The milky juice containing the valuable rubbery substance is not the sap of the tree, as is popularly supposed, but is a fluid held in delicate tubes in the inner layers of the bark. It cannot be drawn out by boring holes in the trunks, as the sap is drawn from the sugar maple. The tubes which hold the juice run lengthwise of the bark, and are so slender and thread-like that, were it not for the pressure exerted by the tension of the bark, the fluid would not flow from their cut ends. To secure the juice, or latex, it is necessary to open up a great number of these small tubes, by wounding the bark. As the rubber is diffused in the latex in the form of minute globules and not, strictly speaking, in solution, and the fluid is held in the tubes, it could not be drawn through their walls within the bark even by a suction pump. Thus, the wounding of the bark to cut as many of the delicate tubes as possible with the least injury to the tree, is the practice followed by the experienced gatherers among the natives.

From almost every tree of the Amazon forests the lianas, or "vejucos," hang as grasping tentacles and gay festoons, and are as strong and tough as ropes and cords. Of these the natives make rude ladders on which they climb the trunk of the tree, and make the V-like incisions covering nearly the circumference, and about three feet apart. As the tension of the bark is mostly exerted in a transverse direction, a transverse cut is often used instead of the oblique cut, and does not injure the tree if it is not girdled or the cut made too wide. There is an objection to this cut, however, in the difficulty of collecting the creamy latex, some of which remains in the cuts, while the surplus runs down the trunk of the

tree and is lost in numerous driblets. The herring-bone method is more generally employed, although in recent years the spiral method is much used, namely, cutting a continuous incision round and round the trunk, in whorls about two feet apart. The advantage in this lies in a greater flow of the latex in subsequent milkings.

In tapping the Hevea the native gatherers use the bush knife, or *machete,* with the end of the blade bent back to form a groove about an inch broad. The cutting edge is well sharpened, and the workers tear gashes in the bark from one-half to two-thirds of the circumference of the tree, and extending up to the lower branches. The latex thus released at first flows out in drops, which go to waste, as it is very thin and watery; but soon the thicker, white, oily liquid appears and is caught in small clay cups placed beneath the incisions. In a few hours the tree has given up its treasure, the yield from each wound being from three to five tablespoonfuls. The gatherer then empties the contents of the cups into an earthen vessel slung across his back, and, after stops at other trees, proceeds to his jungle camp. In some cases it is found expedient to make gashes longitudinally, using a narrow hatchet, and inserting wedges to keep the gashes open. Multiple tapping is the repeated cutting of the edges of the wound to increase the flow of the latex. A Hevea of Selengar, East Indies, thus tapped when twenty-five years old, yielded eighteen pounds of rubber in two months. Another tree yielded twelve pounds ten ounces in the same time. A tree tapped by the spiral method gave twenty-five pounds of rubber in a year, without showing the least ill effect of such treatment.

In the high temperatures of the Equator the latex quickly undergoes a chemical reaction, and soon coagulates, so that the curing process can be begun. The natives make slow fires with the fruit of the auricuri, the flame from the oily but slow-burning nuts making

a dense, black smoke. Over the fires are placed bottomless jars or pots in such a way that the pungent fumes issue through a small aperture, the rubber being cured by being passed slowly over the hot smoke. The biscuits of Para rubber are made by taking stakes of wood pointed at one end, or more frequently shaped into a thin paddle, and dipping them into the coagulated mass contained in earthen basins, when they are held in the smoke until a thin film of rubber solidifies around them. This operation is repeated many times until the "biscuit" is of the desired size. It represents a slow and laborious accumulation of hundreds of dippings, and a number of hours of disagreeable work close to hot fires giving forth ill-smelling smoke. Nut fires are used because the fumes contain certain quantities of acetic acid and creosote which impart to the rubber those qualities which have made Para the highest grade known in the arts. The largest biscuit ever made of which there is authentic record weighed eleven hundred and twenty pounds, and measured four feet five inches in height by three feet five inches in diameter, and was nine feet four inches in circumference. At one time some natives used stones as cores upon which to form the rubber; but the practice was quickly discovered, and, to guard against it, all biscuits are now cut open in halves before shipment, to show the stake holes in the middle.

Upon the upper Orinoco River the Hevea grows rapidly and straight, but to a less height than those of the Amazon, the branches spreading out from thirty to forty feet from the ground and lifting themselves on every side, giving the top a spheroidal shape. The Government of Venezuela prohibits the felling of these trees, which must be countless, since there are seventy-four million acres upon which they exist in abundance. To exploit them would require millions of money, and thousands of men. In gathering the rubber the native

Indians travel from one location to another in canoes, following the streams, and cutting paths through the forest with cutlasses. They seldom delve into the depths of the jungle, but select trees close at hand. They scrape the bark to clear off the moss and rough growth, so that, when cut, the latex trickles over the surface in smooth and clean streams. In Colombia the Government permits the felling of rubber trees, and it is a practice quite generally followed.

Although the rubber trees of the Amazon Valley are well preserved, hundreds of thousands of the species *Castilloa*, which grow on the uplands, are annually killed. This is due to the method of cutting, which yields large quantities of latex, a large tree five feet in diameter giving, when first cut, about twenty gallons; and each gallon makes two and one-half pounds of rubber. The tree sometimes recovers, and may be tapped again in a few months. Many of the trees are killed by the harlequin beetle, which grubs in the wounded bark. When standing near a tree, one can hear their rasping and gnawing of the wood, and the dust from their operations accumulates in heaps at its foot. In coagulating the latex and in extracting the rubber, various processes are used. One commonly employed by the natives is to make a concoction from a liana, which is added to the latex in the proportion of one pint to a gallon. This mixture coagulates to rubber and is dried out in the shade; but before becoming hard, it is moulded into round flat cakes. All experiments of smoking *Castilloa* have resulted in a hopelessly sticky mass. The failure is attributed to differences in the latex rather than to any quality of the rubber.

Another method of coagulation is simply adding about five times the volume of boiling water, and mixing in the solution eight ounces of formaldehyde to each barrel. All the impurities remain in the fluid, and in twenty-four hours the clean rubber is removed from the top in the

form of a snow-white cake. This is nearly free of solid impurities, and is graded as equal to the best Para.

"When the latex of Castilloa is mixed with water and allowed to stand, in the course of an hour or two the caoutchouc particles have all floated to the top in the form of a thick cream. The diluted latex of the Hevea, on the contrary, shows no signs of creaming, even when submitted to low temperature. Difference is most likely due to the larger size of the caoutchouc globules in the case of the Castilloa as compared with that of the Hevea."*

In some places the latex, upon oozing out of the cut bark as a pulpy mass, remains in the furrows, where it is allowed to harden into soft strips of rubber. After two days these strips are drawn out, carefully washed, and dried in the shade, as exposure to the extremely hot rays of the sun makes the rubber sticky and difficult to handle. It is then ready for the market. By this method trees may be tapped four times a year, the wounds being made on a different side each time. The wounds heal in about three months, and the tree recovers entirely, the yield being about two and two-tenths pounds annually.

The natives at Zacualpa use a method of coagulation by which all the non-volatile constituents of the latex are retained in the rubber. They take two large banana-like leaves of the species *Calathaca,* upon which the latex is spread in a thin coating. These are laid out on the hot, bare ground in the bright sunshine, the exposure to heat, light, and air turning the latex black very quickly. In a few minutes the thin film is firm enough to permit of another coating being applied. Then the two rubber-coated faces of the leaves are pressed together and trodden on by the native so that the rubber adheres to form a single leaf-like sheet. When the leaves are stripped off, the thin sheet of rubber is left. Such

* Parkin, Annals of Botany, 14, 198, 1900.

methods as this and the one just described incorporate with the rubber a large amount of albuminous matter contained in the latex, the percentage ranging from nine to thirteen.

The *Pindare* is another species producing large quantities of latex, the flow from ordinary trees being from two hundred and fifty to three hundred grammes in fifteen minutes, while from the Hevea it is from one hundred to one hundred and fifty grammes. The Pindare requires none of the careful cutting and curing that is given the Hevea, one incision only being made in a tree, but the smoking is necessary, and improves the quality of the rubber. It is a low grade of rubber, however, being for the most part nothing but balata, which is a gum containing from thirty to fifty per cent of resin. Although there is a mechanical process which isolates these resins in the latex, the native Indians use very largely their own primitive methods. The fraud is detected by simply dropping a chunk of the so-called rubber to the ground: if pure, it will rebound; otherwise, it will lie like a log, and when compressed in the fingers it will show the impress.

On the Orinoco the trees produce from forty to fifty grammes of latex; on the Rio Negro, from eighty to one hundred; and on the Casiquiare from one hundred and twenty-five to one hundred and fifty, at each milking. While the yield in gum is in direct proportion to the abundance of the trees in the forest, the run of the liquid does not take place at the same time in all the trees. Some with magnificent foliage remain unproductive for years; others yield so little, or it is of such bad quality, that it is useless to collect it. On the other hand, some small trees with short and delicate branches give an abundant supply; and those once or twice tapped but long unproductive, and showing many scars, give no result. The cause of the latex capriciousness is unknown and impossible to determine.

On the Casiquiare in Venezuela, European day-laborers have been employed as rubber gatherers with success. One worker will select about one thousand trees and cut about half that number in a day of six hours. Before beginning work, however, he must spend about eight hours in the forest to mark his tracks and the trees intended to be tapped. The trees stand about fifty feet apart, and five minutes' time is required to fix a reed or clay pipe to each. A record of nine hundred and twelve trees cut daily, produced one hundred and ten pounds of fine dry rubber, which was worth from one hundred and forty-five dollars to two hundred and forty.

The Congo district in Africa ranks second in quantity of rubber produced, and in the interior of the continent there are great forests of rubber trees as yet hardly touched. Rubber trees have also been found on the east and west coasts of Madagascar; but the East Indies now produce but little. The more common grades of rubber reach the market in the form of little black balls, while that brought out from the African coast are ugly flat fragments, called "oysters." The natives working along the African rivers are taught some civilization, and thus become more submissive; and it is thought that Africa some years hence may become the largest producer of rubber, although not of the best grades.

In Ceylon the entire production of rubber is from cultivated trees in immense groves, an industry which promises to be an important factor in the world's future supplies. The latex is there caught in tin cups containing a little water to keep the contents in a liquid state for a time. When quantities have been collected, it is strained and poured into shallow basins. A small quantity of acetic acid and creosote is then added to assist in coagulation, thus supplying the same elements that Nature furnishes the Amazonians in the smoke of their nut fires.

The forest trees of the torrid zone are not the only

producers of rubber; as has been noted, the substance has been found in many different plants, and in some vines. Of the plant life containing it the guayule (wyule) is by far the most important. It is a desert plant of the small shrub kind, and thrives in the arid regions of the north of Mexico and the bordering areas of Texas. The plant is tree-like in shape but rarely attains a height of four feet or a stem diameter of more than three inches. The leaves are small and of a silver-gray color; the blossoms produce small yellowish-green flowers, each consisting of many minute florets; but only five florets in each flower are productive of seeds, and only one seed each. Unlike the latex produced by the trees, the rubber in the guayule occurs in the form of microscopic granules distributed through the fibrous tissues of the stem, branches, and roots. It is much more plentiful in the thin bark, and the only method of gathering it involves the destruction of the plant.

In collecting the plants covering vast areas of desert wastes, the natives uproot them, sparing no part; they pack them in bundles on the faithful burros, which carry them to places where the baling is done for shipment. The cheapness of labor (the wages of the peon being about thirty-seven cents a day, Mexican money) makes it possible to collect the plants in areas as far as forty or fifty miles from a shipping point, the usual means of transportation being the wagon trains drawn by mule teams.

The presence of the sticky gum in the guayule plant has been known since the middle of the eighteenth century, but the production of rubber from it for manufacture, is of recent development. The natives still make rubber balls by chewing out the gum from bits of the bark, a mouthful of it when thoroughly masticated and the fibrous matter rejected, yielding a piece of rubber the size of a pea. It is soft and sticky and difficult to handle. As the granules of rubber are deposited in the living cells

of the plant, special methods are employed to separate it. By one method the rubber is obtained by trituration of the plant, that is, the rubbing to a very fine powder, and a mechanical process for the separation of the valuable from the waste particles. Another method is the use of solvents to separate the gum from the tissues after pulverization.

In Mexico the plants are placed in a grinding-machine (tube mill) which, by means of hard stones tossed about with the mass in a revolving cylinder, soon reduces it to a fine state, in which the gummy substance collects in lumps, with certain amounts of the woody tissue. This is then boiled over steam in an iron vessel with double bottom, the fibrous particles are strained out, and the rubbery stuff is thrown into a tank of cold water. It is again strained, and boiled with caustic soda until all the foreign matter is fully separated. The gum is precipitated by chloride of calcium. In 1890 a German chemist attempted to extract rubber from the guayule in commercial quantities, but not until several years later did the venture prove a success.

By 1905 the production from the Durango consular district was worth only $125,478; but for the year ending June, 1908, the shipments had increased to two and one-half millions. In 1906 the value of the shipments from Torreon was $917,571. The production is increasing, and is becoming one of Mexico's important industries. Millions of capital, thousands of workmen, and enormous tracts of land, are involved. The old Hacienda de Cedros, in the northern part of the State of Zacatecas, consisting of two and one-half million acres, a large part of which is grown over with the guayule, is being worked by one company. Another concern controls three millions of acres, but only the favored locations — generally the foothills of limestone formations — produce the plant in any considerable quantity. A single factory will often use thirty thousand

tons of the plant in a year, which will average about one hundred tons a day, or a growth on from twenty-five to one hundred acres. The number and size of the plants growing on a given acre of the desert vary greatly. Sometimes a stand of one thousand to twelve hundred plants to the acre will be found, and a few of the plants will weigh from ten to fifteen pounds each; but most of them will weigh less than four pounds when dry. The yield varies from one thousand to eight thousand pounds of shrub to the acre; and taking four thousand pounds as an average, a daily harvest of fifty acres is necessary to keep a large factory in operation. It is estimated that in less than twenty years the supply of guayule will have become exhausted.

In the Pijo Mountains of Honduras a vine has been discovered which belongs to the African family of rubber vines. It grows in a wild, uncultivated state to a length of one hundred feet and a diameter of four inches to two feet. It is said to thrive in high altitudes as well as in the low valleys, and its luxurious growth makes it of value for cutting in commercial quantities. The rubber extracted from its latex is equal to the Para grade. Propagation by means of seedlings may be made in rich soil, and the growth is generally much faster than that of rubber trees.

Rubber, as an article of commerce, first made its appearance in the United States in 1821, in the welcome form of overshoes. Being introduced as the original Para rubber shoe made by the native Indians, and in the rough and unfinished state, they well represented the unskilled work of primitive man. Nevertheless, more than five hundred pairs of the shoes were imported and sold in Boston in 1828. As early as 1823 Charles McIntosh discovered a process of dissolving rubber in benzine, which was the beginning of the waterproof-clothing industry. In 1832 Chaffee and Haskins, of New York, founded the Roxbury India Rubber Company, for the

purpose of manufacturing rubber goods, all of which had previously been imported into this country. But they were unable to perfect any process of overcoming the characteristic stickiness and adhesiveness of the crude gum, and the business was not a success. They had in their employ, however, Charles Goodyear, who set about to discover some practical methods of overcoming these difficulties; and, in 1839, he demonstrated a combination of rubber and sulphur in certain and exact proportions, which was the actual beginning of the rubber industry. By working together these ingredients under pressure and proper temperature, it was found that the product would not break at a low temperature, nor would it become sticky at a high one. To this process, called vulcanization, is due the great and ever increasing use of rubber in the mechanical arts. The advent of the "Goodyear" shoe in Providence marked the end of the importation of Para rubber shoes, which for fifteen years had the entire market of the United States, without competition. S. C. Smith, of Providence, was one of the first to manufacture rubber goods from the sheets of gum imported from Para, into shoes and other goods.

By 1854 the exports of rubber from Para alone amounted to three million six hundred and eighty thousand pounds, and one hundred and sixteen thousand four hundred and fifty-five pairs of shoes. From 1866 to 1871 the average annual yield of the Brazilian forests, as reported to the Vienna Exposition in 1873, was ten million pounds, which indicated a rapid growth of the industry. Although no crude rubber was used in the United States prior to 1839, it now uses one-half of the world's production. This amounts approximately to one hundred and twenty-five million pounds annually, of which sixty per cent, or seventy-five million pounds, is produced in the Amazon Valley. The average annual increase of the Para crop in a period of twenty years was eight per cent, but for the five years previous to

1908 it was only four per cent. The largest increase for a single year that was recorded was seventeen per cent. The market value of the total production to the exporting countries is fully eighty millions of dollars, of which about sixty-five per cent or fifty millions passes through the port of Para alone. Europe and America use practically the same amounts of crude rubber, but the latter consumes a larger proportion of the Para grades. In 1904, during a time of high prices, America used Para rubber to the value of twenty-eight millions, or fifty-four and four-tenths per cent of the total crop, while the European consumption was twenty-three millions, or forty-five and six-tenths per cent of the total crop. In 1907 crude rubber reached a price in the United States of one dollar and fifty cents a pound; but in the London market the needs of the trade and the uncertainty of the supplies, have at times forced the price much higher.

The world's principal distributing markets are New York, London, Liverpool, Antwerp, Hamburg, Lisbon, and Havre. Liverpool alone imports nearly all of the Para stock that the United States does not use, or about forty per cent of the total. London is the direct market for the Rangoon, Assam, Penang, Borneo, Mozambique, and Madagascar grades, and those produced at points below Bolivia. The Antwerp market takes all the rubber from the Congo, amounting to about eleven million pounds; at an average price of seventy cents a pound, this amounts to seven million seven hundred thousand dollars. One concern alone controls ninety-two per cent of the imports, which have been practically of the same amount the last seven years. To Hamburg goes the product of East Africa, West Africa, the East Indies, and Central and South America. The product from cultivated trees is yet so small that it is hardly appreciable in the total supplies. Most trees do not produce latex until they are fifteen years old; those of the Hevea are not of value as producers until twenty years

old. It is estimated that in 1907 the cultivated trees produced not more than two hundred thousand pounds of rubber.

Although the culture of rubber-trees began as long ago as 1872 and the industry has been exploited by many concerns, any considerable supply of rubber has not been obtained from this source. The many difficulties in the way of securing Nature's gift from the jungle are multiplied in the attempt to encourage her in the production of the valuable substance in favored and selected places. For, as has been proved by numerous experiments resulting in failure, man's choice of locations is seldom that in which the earth's forces and the elements of light and air combine to grow rubber-trees of commercial value. The difficulties of nurturing the seedlings, the transplanting of the small trees, their cultivation for a period of years, and the control of the natives, are manifold; and even when the soil and climate are favorable there are many obstacles in the way of gathering the latex and curing the rubbery substance. But despite the discouragements and financial losses, the planting and culture of rubber-trees goes on apace, and it is estimated that in 1912 at least nine million trees will come into profitable bearing. A minimum calculation shows that this supply will not be more than ten per cent of the world's production. The constantly increasing demand for rubber, and the high prices, with promises of fat dividends, are the spurs that draw the hoards of money from all classes of the people. Speculation has been rife at times, and not infrequently women of social standing have been compelled to raise money on their jewels in order to meet assessments on their shares of stock.

Rubber-trees, when given intelligent care and cultivation, grow rapidly after first getting a good start, and it is this favorable feature of the industry that entices many investors. But rapidity of growth is in inverse ratio to the formation of the rubber globules in the tissues

of the bark; and excessive irrigation to hasten the growth sometimes reduces the rubber content to such a degree that it is unprofitable to extract it. The trees thrive best in lands having an elevation of two hundred to twelve hundred feet above the sea level, and enjoying a rainfall of at least one hundred inches. The soil should be rich in tropical decay, the climate hot and humid, and there should be some forest growth to furnish the shade which rubber-trees crave. To this last requisite is probably due the partial success of planting rubber-trees in the mahogany forests of Central America. The cutting of the valuable timber and the consequent clearing of the ground for the planting of rubber trees, furnishes a revenue from the land until such time as the new growth comes into bearing.

The flowers of rubber-trees native to the Amazon Valley are small, and are borne in little sprays. Each of the dried fruits contains three seeds about the size of Kentish cob nuts. They are very oily, and unless carefully handled and properly stored, soon lose their vitality. In shipping the seeds great care is taken to pack them in tins in dry powdered charcoal, cocoanut-fibre dust, or sawdust. For long journeys they are often planted in Wardian cases, which are boxes having glass covers and provided with rich soil and proper moisture, in which the good seeds germinate during transit.

In the early cultivation of rubber trees, the beautiful Kew Gardens on the River Thames in England, played an active part in founding rubber plantations in the Far East. It was in 1875 that H. A. Wickham, a planter who believed that fortunes awaited the growers of the Hevea, interested the Kew Gardens and the India Office in the project, and he was commissioned to collect Para rubber seeds for experiments. The following year he brought them to Kew Gardens and, although only a small proportion of the seeds germinated, in a few months nearly two thousand healthy Hevea plants were sent to

the Botanical Gardens in Ceylon and in Singapore. Later, some seedlings and saplings were planted in the museum grounds at Taiping. Although there was little interest taken in the project at the time, and some were not successful, the business gradually grew into importance, and now it is a valuable resource of the British possessions. In certain cases trees seven years old, and measuring fourteen to sixteen inches in diameter, have yielded four pounds of rubber, while others a year older have given five pounds. They are generally planted fourteen feet apart, or two hundred to an acre. Ceylon alone, since the rubber boom was started, has planted sufficient trees, should the usual number come to maturity, to supply London with fourteen million pounds of rubber yearly. The land suitable for their culture was purchased by syndicates at high prices, and the enormous capital employed in the gigantic operations insures the permanency of the industry.

On the Malay Peninsula the cultivated rubber is of a different and distinct grade from any other, and is twenty-five per cent lower than Para in quality. It meets a ready market, although it is not suitable for the making of rubber bands or other elastic goods. The gum in solution loses its tenacity so that it cannot be used for cements; and it softens with age. The good prices obtained for it are due to its clean appearance and the brokers' preference rather than to factory tests. In Java the Hevea, and the Castilloa of Central America, were, because of soil and climate, discarded in favor of the Ficus which produces the Assam rubber of commerce.

In Mexico much time and treasure have been spent in vain attempts to cultivate the guayule plant, but certain obstacles render the cost excessive and above the value of the product. Of the total number of seeds planted there is a possible germination of only ten per cent; and the failure of the young seedlings to survive the early stages of development and to withstand a pest and

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SOFTENING AND WASHING CRUDE RUBBER AS IT COMES FROM BRAZIL
[See page 155]

HUGE CALENDERS WHICH COMBINE THIN SHEETS OF RUBBER WITH FABRIC, USUALLY A SEA ISLAND COTTON
[See page 157]

PREPARING "TREAD" FOR VULCANIZING

TWO-PIECE MOULD WITH TREADS BEING PLACED FOR VULCANIZING

parasite, together with the usual accidents in transplanting by semi-barbarous natives, make it doubtful if more than one per cent of the seed sown, even under the most favorable conditions, mature into productive plants. Under the natural desert conditions the growth is very slow, and the crop is seldom brought to a profitable bearing state within fifteen or twenty years. Rubber is present in the plant, however, long before maturity, and some planters have been able to obtain it in moderate quantities in twelve to fifteen years. Irrigation, on the other hand, hastens the growth, so that in four years a plant will sometimes weigh six pounds, but the rubber-content will be very little; while in a desert plant of the same growth it is about ten per cent of its dry weight. The natural processes of reforestation are likewise slow, and the growth is never equal to the first. It is estimated that a guayule seed cast off in the desert has but one chance in ten thousand of germinating; and even should it do so, its hold on life, because of drought, pests, and accident, is very uncertain. It would seem that the only way to prolong the guayule rubber industry is so to harvest the plants that the roots are left in the ground. If this be properly done the roots will grow new shoots, and in a few years a new plant may possibly yield another crop well worth gathering.

Another obstacle to profitable rubber-culture is the theft of the latex by the native population; in Central America some planters have given up the business because they could not guard their trees and prevent the killing of them by the persistent thieves. Although the trees grew and became of commercial value, the owners could not harvest their crops. Because of the high value of rubber, the ease with which it is taken from the cultivated trees, its small bulk, the long time it can be stored, and the facility with which it can be taken to market, the thieving is an established practice of the natives, and the owners never handle any of their own product, unless

they buy it back from the natives, and even from their employees. They are saved, however, the cost of gathering and curing the product of their own trees.

Within the last two decades rubber has come to be regarded as a prime necessity of life. Not only is it indispensable for various uses in the medical and surgical professions, but it is invaluable in the mechanical arts for the perfecting of numerous articles which insure the safety of life and treasure. Without it the air-brake and the steam-heating of railway cars would be impossible; and there would be no practical insulation of electrical conductors, and no suitable tires for automobiles. Without it the useful waterproof clothing and shoes and boots would be unknown, as also the hard-rubber specialties in which it is used as a substitute for whalebone, tortoise-shell, and ivory.

In the process of manufacture rubber is not melted, as is generally supposed, but is heated until soft, and moulded or compressed into the exact form of the article desired. It may be made hard or soft according to the proportion of sulphur with which it is compounded in the process of vulcanization; it may be rendered flexible or inflexible, and may receive the required degree of elasticity or of resiliency by the treatment it undergoes. Garden hose, fire hose, air-compressor hose, steam hose, and suction hose, belting and packing for machinery, moulded and perforated door and carriage mats, floor-coverings, horseshoe pads, and fruit-jar rings, are some of the common products of which rubber is the basis. In the purchase of the raw material as it comes from abroad, much care must be taken, as it varies vastly in composition and quality. Careful tests also must be made to determine its adaptability to specific uses. Great skill is required in the cleansing, compounding, and manufacture.

The hundreds of useful articles made of rubber in the United States, may be divided into four classes, namely,

shoes and clothing, mechanical goods, hard rubber goods, and druggists' sundries. In point of value the first two classes are the most important. In 1907 the value of rubber boots and overshoes, at net jobbers' prices, exceeded fifty millions of dollars, and that of mechanical rubber goods was about forty-five millions. The great expansion of the industry within the last twenty years has resulted in a combination of the rubber interests, in which the Rubber Goods Manufacturing Company operates about twenty of the largest factories in the country. It is by far the largest rubber-manufacturing concern in the world, and has an enormous capital to carry on a business the annual sales of which approach one hundred million dollars.

To what extent modern factory equipments, operated by skilled workmen under a perfect organization, tend to produce goods of a uniform standard of excellence, and to reduce the cost of production, is graphically shown in their new Detroit plant, which was completed and put in use in 1907. In all the industrial world it would be difficult to find a more excellent example of factory construction or a better scheme of arrangement of buildings and machinery. By carefully working out every detail in the plans, there has resulted a surprising economy of power distribution, with the most convenient handling of the materials and ingredients in the processes of manufacture; and abundance of light and air is afforded the army of fifteen hundred workers within the walls. By the latest approved methods in factory the quality of the products is greatly improved, so that they give better and longer service to the user, as is notable in motor tires. It all results from the experience of twenty-five years of the Morgan and Wright division, and the practical knowledge of scores of experts in the great rubber concern.

The mammoth power-house is an integral portion of this splendid equipment of machinery; and, as power and

live steam are two of the principal factors in rubber-goods making, it is an all-important part of the works. There are two great engines fitted with Corliss valve gear, and rated at eighteen hundred horse-power each. The distribution system for the power is arranged to conform to the peculiar requirements of rubber-working. In the main buildings are the ponderous rolls, the huge calenders, and the heavy presses, which exemplify most vividly man's control of raw materials. These machines run at low speed, but are large consumers of power. The main engines deliver the requisite power from eighteen-foot fly-wheels by the American system of rope drives, to twenty-two-foot receiving sheaves mounted at the ends of a heavy jack-shaft, from which the power is distributed throughout the plant. There are also the big cylinders for curing the rubber, the mixers, the vulcanizers, and numerous small machines which use enormous quantities of steam. All these and the main engines, the pumps, and fire and heating systems, are supplied with steam at a working-pressure of about one hundred and fifty pounds, by a battery of ten vertical water-tube boilers, fitted with mechanical stokers, ash-hoists, and blowers.

The first operation in making rubber goods is the purification of the raw material as it comes from abroad. In this process one may see the crude rubber from Brazil dumped into a large square tank built of concrete and fitted with steam and hot-water pipes, for the purpose of steaming it into a soft, plastic mass. It is then thoroughly washed by passing through machines having heavy rolls, which mash and knead it between their hot surfaces, and which are aided in the operation by much water sprinkled from above. After passing through several of these washers it comes out in thin sheets, a porous substance resembling sheet sponge. In this state it is placed in vacuum dryers of quite recent invention, that are revolutionizing the methods of drying rubber; for it must

be dried before it can be further worked up. The vacuum dryers are fitted with automatic devices by which an even pressure of thirty-eight pounds, and a vacuum of twenty-seven inches, are maintained. They effectually remove all moisture in the rubber in two and a half hours. In the old process three months was required for the same results. On the fifth floor is the large drying loft, the hot, dry air of which is kept at a uniform temperature of one hundred and ten degrees Fahrenheit. Here, in racks upon racks, are hung the loose porous sheets of fine Para rubber. As the works use fully five thousand pounds of washed rubber every work-day, the stock in process of drying and working through the various departments, together with the reserve supplies in warehouse and in transit, is very large, and represents an invested capital of considerably more than a quarter of a million dollars.

As the stock becomes thoroughly dry it is taken to the main floor of the mill building, where it is run through the rubbing and crushing rolls. This operation reduces the mass to the consistency of a soft plastic ball, and it is moulded into rolls about twelve inches in diameter. It is then ready for the process which prepares the rough stock for the various treatments in the different departments of the works. The mixing-room is an interesting place, for here the sulphur and other ingredients that are used in working up the rubber are mixed in exact proportions, each part being weighed out with painstaking care. It is here that the fine skill and thorough knowledge of rubber-making by expert workmen, is manifest, as nearly every separate article made requires a special compound. The finished stock to go into motor tires must be very different from that which goes into garden hose, horseshoe pads, or belting. To determine the best proportions to use for specific purposes, such as the gaskets for the steel tube joints of the Detroit River Tunnel, a complete laboratory, which is very like a miniature rubber

works, is maintained, wherein are solved many problems in rubber-making.

The proper mixture being made, a correct quantity of rubber is cut from the moulded chunks, and all is well rolled and kneaded together between the hot rolls of other mills, until the mass comes out a sheet of prepared rubber about a quarter of an inch in thickness. It then passes into the products building adjoining, and one may see a particular lot going through the various processes in the making of motor-tires. Through the length of the main floor there are huge calenders, their triple rolls sizzling hot, pressing out the sheet rubber into thinner sheets of parchment thinness. Between the lower rolls a wide strip of sea-island duck is passing, and the thin rubber from above is brought down to it. The rolls revolve at different speeds so as to produce a rubbing in action in addition to the pressure exerted. This operation results in the rubber's being more than simply pressed into the mesh of the canvas, as it is ground into the very threads and fibres of the duck, which adds to the wearing quality of the tires. As the rubber cloth — as it has then become — leaves the rolls, it is cut into strips of proper width, and wound on heavy cloth to prevent the surfaces from sticking together. The friction fabric, which is another part of the tire casing, is prepared in much the same way, the rubber being worked in so that each thread will be firmly united to the rubber casing stock in the process of vulcanization. It is then cut by hand, on the bias, into strips when it is ready for the tire-builder.

Up on the fourth floor one may find these artisans busy at their reels, building up the casings step by step, rubbing together the alternate layers of friction and fabric, trimming edges here and there, and forming the inner rims to conform to the models of the M and W clincher and the Dunlop perfected rims. With machine-like precision these skilled workmen go through the varied ac-

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VULCANIZING PRESSES

BUILDING UP MOTOR TIRE CASINGS

VULCANIZING TUBES

tions necessary to the work, all the motions of arms, hands and fingers being made without a single false move. Every effort and every moment count for something, so that in two to two and a half hours the casing is built up ready for its covering of rubber and the very essential process of vulcanization.

This important process cannot be observed, as the combining of the rubber, the fabrics, and the cement into one uniform and evenly smooth form is scientifically accomplished in huge cylindrical ovens. After remaining in one of these for about ninety minutes, the casing is removed, the wrappings of stout cloth, which were put on to keep the casing in form closely about the iron ring, are unwound, and the casing passed on for its next inspection. One is impressed with the care exercised by every workman to do his particular task absolutely right in every detail. Following him an inspector examines the work before it is passed to the next process, and so on through the entire works. A certain thing done, a rigid inspection follows; other work done, another inspection; and on through the stages of manufacture until the finished product passes a final examination and test. It is stated that on an average only one tire in one hundred is put down as a "second."

To complete the casing and to give it wearing qualities, the tread, which has been calendered and formed to the practice of the Bailey and other non-skid treads, is fastened on and made ready for the final vulcanization. To effect this the casing with the tread in place is put into a two-piece mould, which in turn is put into a press between steam-heated plates. Hydraulic pressure is applied, and the heat vulcanizes the casing and tread into the finished casing with its hard and tough wearing surface and stout fabric within.

The making of the tubes is an exceedingly interesting process. The stock is first mixed and calendered to an even thickness, and cut to the proper length to correspond

with the size of the casing for which it is intended. A steel tube mandrel is placed at one edge of the strip and rolled over and over, just as a piece of paper is rolled around a pencil. The tubes are then piled on cars and run into a heater to be cured. After curing, the rubber is removed from the mandrel, coming off in the form of hose. These are then passed along to benches, where workmen clip off the rough ends, measure to the proper length, and punch the valve-hole. When they are placed on racks other workmen turn back the ends and coat them with vulcanizing cement. After drying for several days the ends are turned into place, the cemented surfaces are pressed together and placed on steam pipes, which by heat and pressure vulcanize the ends together. The tubes are then ready for the inspection tank where each one is inflated and tested in water; and then they go to tables, where valves are inserted and clamped in. After a final inspection the tubes are ready for the trade.

In making hose, the inner layer or tube is first formed by taking sheets of unvulcanized rubber and cutting them into strips, which are fed into a tube-forming machine. This is in principle quite similar to a household meat chopper, having a worm conveyor which feeds the material from a hopper to a tube-forming head. The rubber in a plastic state is forced through an aperture of the required size, in which the core is centred; it then issues from the die (which gives the desired gauge) in the form of a seamless tube strongly knit together, and is coiled on a revolving table. The tube is then slipped over an iron rod by simply inserting one end and inflating the hose slightly by attaching the other end to an air-compressor pipe. A thin cushion of air is thus formed in which the rod is "floated" into the tube. This method also serves as a test, for any imperfection in the tube will be quickly revealed. When the tube has been coated with cement it is placed in a winding machine, which consists of three long rolls that engage the tube

BUILDING UP SINGLE TUBE TIRES

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on three sides throughout its length, and layer after layer of rubber-coated canvas is wound on. The edge of the bias strip, which is made of diamond-shaped pieces cemented together to preserve flexibility, is inserted between the rolls against the tube, and to the opposite edge of the canvas a covering strip of rubber bearing the brand, is cemented. When the rolls are set in motion revolving the tube, the layers are wound tightly together. The whole is then wrapped with linen to prevent swelling and distortion in vulcanizing. This process takes from twenty minutes to an hour, according to the grade of rubber used; and when removed from the rod by inflation, the hose is ready for shipment. Fire, steam, and air-brake hose are made in much the same way, but the tubes are of at least three calenders or layers of rubber turned out by hand, instead of being run from a tubing machine.

Owing to the increased use of high-pressure and superheated steam, much attention is being given to the making of special rubber packing to meet the needs of such exacting service. The high temperature and strong pressure make necessary a compound, containing certain ingredients mixed into the "batch" which absorb the excess of sulphur, to resist further vulcanization during use. The best packing is made by combining the waterproofing qualities of rubber, the heat-resisting and insulating qualities of asbestos, and the tensile strength of brass wire. These materials are so fabricated that the rubber coating prevents disintegration of the asbestos, while the wire prevents "blow-outs." A woven wire cloth is first wrapped with asbestos, which is coated with pure rubber on both sides, and the whole is compressed into a closely knit fabric in hydraulic presses. For permanent joints another packing is made of rubber and graphite, the former being put in unvulcanized. It contains, however, a requisite amount of sulphur, so that when placed in the joint, the heat of the steam vulcanizes it and moulds it into place. The graphite aids in filling

up uneven surfaces with which the packing comes in contact, and it retains its form unchanged.

Interlocking rubber tiling is a useful product of the works that is in demand for floor-coverings in public halls, lobbies, and stairs. Unlike the old method of manufacture, in which the materials were cut to the form of tiles and vulcanized separately in moulds, the present improved method is to make it up in sheets, rolled to gauge, and vulcanized in large hydraulic presses under three thousand pounds pressure, thus insuring a uniform density and thickness. To reduce the cost of production, fruit-jar rings are no longer stamped from sheet rubber, but are cut from rubber tubing made by the same process as hose. There is no waste in stamping, and the cutting is an economical process. The vulcanized tubing is placed on a mandrel which is revolved in a lathe, and an automatic cutting device presses a sharp knife against it at intervals, cutting a ring at each turn. Rubber dredging-sleeves as large as thirty-three inches in diameter and seven feet long, have been made for forming the flexible connections between the sections of piping, which are carried on pontoons, for the discharge of the dredged material. The uses of rubber in its vulcanized form are so many that it would be a hopeless task to attempt to specify them; but pure rubber is now used only to a limited extent in the arts.

Although it is now quite impossible to buy a pure rubber article in the market, the manufacturer is not at fault for this condition, and the purchaser should not complain of the quality of the goods he receives. The fact is, he will not pay for the finished product more than one-fifth or one-fourth, pound for pound, of what the crude rubber cost to the maker. A concern will pay, say, one dollar and fifty cents a pound for the crude rubber, and twenty-three cents a pound for the canvas, yet it makes and sells rubber hose to the user for twenty-five cents a pound. The weight of the canvas is relatively small,

and, as there can be no adulteration of it, the cheapening of the finished product must come out of the rubber. The sources of crude rubber are, however, not confined to the forests of tropical countries, for, since the invention of a process of reclaiming old rubber, large quantities of the scrap, or "shoddy," as it is called in the trade, are collected and worked up into new goods. The amount of reclaimed rubber in the United States is at least fifty million pounds a year, and to a large degree determines the market price of the new raw material.

After long use rubber generally loses its elasticity, and the fabric with which it is combined disintegrates, but the rubber itself remains. It does not decompose, nor is a particle of it lost except by frictional abrasion; and it is still moisture-proof and of great value. It can be used, sometimes with new stock, for all purposes excepting those requiring great elasticity and the highest tensile strength. It is useless, however, as long as the sulphur in its composition remains, but that ingredient is effectually eliminated by the reclaiming process, called "devulcanization." This reduces the rubber to nearly its original workable state, as the sulphur is thoroughly nullified. The "shoddy" is principally worn-out boots and shoes, but may include every form of disused rubber goods. The poorest grade of garden hose, inner tubes, and pneumatic tires, often contain pure rubber to the amount of two-fifths of their weight.

To remove the adulterants with which the rubber was originally incorporated, the scrap is first ground very fine, and, by a mechanical process through the use of magnets, sieves and blowers, the metal and fibrous substances are easily separated. The grinding-machine, which, like much of the machinery in the rubber works, is of large and heavy construction, has two parallel rolls, one of which revolves faster than the other. The scrap is fed between these rolls and crushed and ground until it comes out on a belt conveyor for delivery to an elevator,

which lifts it up and deposits it on inclined vibrating screens. The finer particles are sifted out, and the coarse stuff is returned to the grinding-machine for further treatment.

The fine clean powder is then mixed with certain compounds which, when the whole is subjected to heat, combine with or absorb the sulphur therein present, and carry it off. This process is accomplished in a large steam cylinder, in which several tons of the material are run in at one time. When steam is admitted, the temperature soon rises to three hundred and twenty degrees Fahrenheit, and is maintained for twenty-four hours, the sulphur being extracted and leaving an inert, plastic substance. This is composed of pure rubber and the compounds with which it was first mixed for the early processes of manufacture. The mass is dried and passed through other grinding-machines, thus reducing it to convenient form for mixing a "batch" of rubber. The standard compounding ingredients to make this are: certain quantities of refined "shoddy," whiting, white-lead, oxide of zinc, and sulphur from three and a half to ten per cent by weight. The proportions are determined by the character of the rubber desired. These are thoroughly mixed in grinding-machines and moulded to the required forms, or rolled into sheets of any thickness.

Another method of treating "shoddy" after the foreign substances have been removed is to steam it with soda and lye under pressure, then to wash it twice for the elimination of the lye, and to dry it in vacuum dryers. It is then mixed with from five to ten per cent of benzol or mineral oil between cold rollers, and steamed for some hours under hydraulic pressure, after which it is rolled into plates. There is the disadvantage in this that it cannot be stored long, as it hardens and is likely to catch fire.

VI

LEATHER

THE ART OF TANNING AND THE MAKING OF LEATHER GOODS

TANNING DONE BY EGYPTIANS, CHINESE, AMERICAN INDIANS — INTRODUCED INTO MASSACHUSETTS AND VIRGINIA — THE ACTION OF BARK ON SKIN — VARIOUS SKINS USED FOR LEATHER — TANNING IN ENGLAND AND SCOTLAND — SPECIAL USES FOR WALRUS-HIDES — ALLIGATOR LEATHER — CHAMOIS — TANNING MATERIALS — HOW TO DYE AND WATERPROOF — UTILIZATION OF WASTE LEATHER — LEATHER INDUSTRY OF THE UNITED STATES — SHOEMAKING — SHOE MACHINERY — METHOD IN LARGE FACTORIES — A HUNDRED MACHINES TO MAKE ONE SHOE — CAPACITY OF A LARGE FACTORY — LEASING MACHINERY — KID GLOVES — POORLY FED ANIMALS YIELD POOR SKINS — SCOTTISH GLOVERS INTRODUCED INTO AMERICA — DETAILS OF GLOVE-MAKING — LEATHER FOR BOOKBINDING.

LEATHER is one of the most valuable and indispensable products of the animal kingdom, and must be regarded as ranking next to food products and wool and cotton fabrics in the list of commodities necessary to the human race. It possesses the desirable quality of durability, which gives it a wide field of usefulness, and it is supple and porous according to the treatment it receives in manufacture. The tanner, in both the primitive crude methods and in modern processes, removes its tendency to putrefaction, and incidentally increases its strength, durability, and imperviousness to water; while the currier by further manipulation renders it soft and pliable and gives it the proper finish and coloring for special purposes. These are connected with a wide range of useful articles in the industrial world, in addition to the more common uses in the mechanical arts. Among footwear, gloves and mittens, coats,

aprons, and headgear, harness, belting, and valve-packings, polishing-wheels, and many other articles, there is wide variety in respect to quality, texture, and color.

Like all the primitive methods of working up raw materials into useful products and articles of wear, the original process of curing skins was probably not more than simply cleaning and drying them, and very likely it began before the dawn of history. As time passed an awakening instinct of the savage led to the discovery that smoke, the sour milk of goats, certain oils extracted from vegetable matter, and even the brains of the slain animals, when rubbed into the skins improved the texture of the leather. Later developments resulted in the use of certain astringent barks and acids to stop the decay of the skins, and to give the leather desirable qualities of toughness and durability. As in the case of nearly all arts and sciences, the Egyptians were the first people within the historic period to possess this knowledge, as is proved by engravings on their tombs depicting the process of tanning. The Chinese have handed down through ancient deposits specimens of leather which, discovered with other relics of great antiquity, proved to be over three thousand years old. The Romans at an early date in their history made leather from skins by tanning them with oil, alum, and bark.

Among the aborigines of America the preparation of skins of wild beasts, to arrest their proneness to decompose, must have antedated the earliest germs of civilization. When discovered by the early explorers the native Indian wore the skins of animals, which naturally were among the first articles of clothing; but any means of preserving the skins more effectually than by simply drying them, were then most crude. Their primitive method of dressing the skin was laborious; their only tools were made of stone and bone, and the leather was rough and hard; but it answered their needs. Upon slaying a beast of the forest or the plains, they removed the skin with

a sharp flint flake; they cleansed it thoroughly with water; and then they treated it with smoke, buffalo dung, oil, clay, or the brains of the animal itself, to prevent putrefaction. A slow drying, with the hair or fur still on, rendered the skin fit for use.

It was early in the seventeenth century that tanning on a commercial scale was introduced into the American colonies, but whether the first tannery was operated in Massachusetts or in Virginia is a matter of some doubt. It is certain, however, that the industry developed much more rapidly in Massachusetts than in any other colony. In those days the practical knowledge of tanners was limited, and their facilities and tools for making leather were very crude. The discovery that bark of some kinds of forest trees when applied to the skins had the effect of preventing decay, was doubtless the result of accident, the circumstances of which have long since been lost in the vista of time. The tanners made crude boxes of rough planks and sunk them in the ground for vats, and they prepared the bark of the oak, which was the best tanning-agent, by crushing it into fine particles with heavy stones. They then soaked and rinsed the skins in water, removed all pieces of flesh with a sharp knife, and loosened the hair by the use of lime. In the process of tanning they sprinkled the fine bark over the bottom of the vat; upon this they laid a side of skin, then another layer of bark and another skin, and continued the alternate layers until the vat was nearly filled. The mass was then covered with water and allowed to soak for six to eight months. The skins were taken up and the bark was renewed at intervals, but they were not finally removed until thoroughly tanned. The heavier and thicker hides, tanned for sole and upper and harness leather, were soaked for a longer time.

The principle of the action of bark on the soft animal skin was unknown until about the beginning of the eighteenth century, although the same unvarying method had been employed from the earliest times. But with a better

knowledge of the properties of skins and the bark, improvements were made, as shown by an old print of eighty years ago:

"It is a simple process to make leather of hides and bark, but probably one of the most critical of manufacturing operations to make the most and the best leather that can be made from a given quantity of hide. The process is long and laborious. Time and labor are materially reduced, and the quantity and weight of the leather increases, by various improvements which commenced in the year 1803, in Hampshire county, in Massachusetts. The improvements alluded to are the substitution of water power for manual labor, in many of the more laborious parts of the process; namely, to soften and cleanse the hide preparatory to the bark being applied to it; to grind the bark; to move pumps for transferring the decoction of the bark from one vat to another (much of which is necessary to be done daily in an extensive tannery), and to roll the leather preparatory to its being sent to market; also the least possible quantity of lime is now used to facilitate getting off the hair. This has been found greatly to add to the weight and quality of the leather.

"The application of heat to bark in leaches is found to be very important, and more particularly the application of the decoction (usually termed *liquor*) to the hide, rather than the bark, which had been commonly employed. In 1829, 36,360 sides of sole leather were tanned in one establishment in the town of Hunter, Greene County, New York. They weighed 637,413 pounds, and were manufactured with the labor of forty-nine hands, and with 3,200 cords of bark. The tannery has seven powerful waterwheels adapted to the various machinery. Slaughter hides averaged fifty-six and a half pounds of sole leather from one hundred of hide; best South American dry hides gained sixty-one per cent in weight, and ordinary ones in proportion. Tanning is a chemical process; and undoubtedly the art will go on improving with the progress of chemical science and the diffusion of chemical knowledge."

As the uses of leather increased, and the demands, especially from boot and shoe makers, became greater, its manufacture for various purposes was much stimulated,

and, although the industry labored under a heritage of ignorance and prejudice, it finally attained large proportions.

"The use of machinery was discouraged, new formulas and processes were frowned upon, old-style methods and ideas prevailed, and, despite the fact that the art of tanning depends upon chemical action and reaction, the scientific knowledge of chemicals was repulsed. However, a change finally came. Chemistry, which had done so much for the advancement of other industries, fought its way in against the combined opposition of prejudice and ignorance, and revolutionized certain branches of the industry. Other branches were touched with the spirit of progress, and during the last few years advancement has been as rapid as previously it had been slow." *

Compared with the enormous quantities of pelts obtained from domestic animals the supply of skins from all aquatic mammals, such as seal, walrus, alligator, sea-lion, sea-elephant, and white whale is so small as to seem inconsiderable. The very rarity of such skins and the difficulty and danger encountered in obtaining them, render the leather thus made of high value, although the aggregate represents a sum not comparable with that of the general leather supply. Of this class of skins the seal reaches the highest value, or one million five hundred thousand dollars annually; alligator skins are worth five hundred thousand dollars; and those of the white whale, or beluga, bring fully two hundred thousand dollars. The latter hides make, perhaps, the best of all heavy, tough leathers in respect to strength, pliability, and durability; it is often sold as porpoise leather. The skins of this class are nearly always obtained in a damaged condition due to the whales fighting among themselves.

The seal-skins used for making leather are obtained from the species which is quite destitute of a coat of fur, and distinct from fur seals whose skins are of great com-

* Census Bulletin, 72, p. 52.

mercial value. The former seals, however, because of the high value of seal leather and the oil products obtained from them, are of only slightly less economic importance than fur seals. They are found in northern waters, off the coast of Labrador, Newfoundland, Greenland, and the north of Europe, and also in the North Pacific and in the Caspian Sea. The Newfoundland fisheries are by far the most extensive, and are the most important of all the marine industries of the world. Although seal-fishing is a most hazardous occupation, more than five thousand men are directly employed in it, and thousands of others are engaged in preparing the products of leather and oil. Strictly speaking it is not an American industry, as only in a few instances are vessels flying the Stars and Stripes engaged in the fishery. The returns from the annual seal-hunt off the northeast coast of America are reaped for the most part by fishermen from Scotland and Newfoundland. In a single year the total product amounted to three hundred and forty-five thousand skins, of which twenty-seven thousand were young hoods, or bluebacks, thirteen thousand were old hoods, four thousand were bedlamers, ten thousand were old harps, and two hundred and ninety-one thousand were white coats, or young harps. The product of the world totals about six hundred and fifty thousand skins, valued at six hundred thousand dollars.

The young seals less than fifteen days old are called "fast-furs" and their skins are known as wool-seal, because of the long hairy covering, thick and woolly, which is not easily separated from the pelt. The skins of the young harps, when cleaned, average five to six pounds in weight, and are worth eighty or eighty-five cents each; bedlamers' skins average twelve pounds and sell for one dollar and thirty cents; old harps vary from fourteen to eighteen pounds, and are valued at ninety cents; young hoods, or bluebacks, weighing six to seven pounds are worth one dollar and thirty-five cents; and old hoods of from fifteen to twenty-four pounds bring as high as one

dollar and sixty-five cents each. The skins of the females are preferred to those of the males, as they are generally free from cuts and other damage about the neck and fore flippers, which are common in the males. The Norwegians, because of their economic outfits, are now almost the only seal-fishers in the north of Europe who find it a profitable industry.

When obtained along the Newfoundland coast, the pelts are simply cured to preserve them for tanning in foreign countries. The skinners remove the blubber, take out the flippers, cut off the noses, and otherwise trim the skins, and pass them to other workmen, who pack them down with dry salt, one skin over another, with the flesh side uppermost. In small piles thus formed the skins remain for three weeks, when they are shipped abroad or to the United States for tanning. Much of the product is sold in London, although Liverpool, Hamburg, St. Petersburg, Moscow, Dundee, and New York take considerable quantities. The United States use from seventy-five thousand to one hundred thousand seal-skins for leather-making annually.

Seal-skins are thick and heavy, but except for the characteristic of extreme oiliness, they do not differ materially from other raw skins; and the process of tanning is quite similar to that used for other pelts. There is the "liming" process and the "fleshing"; the former softens and removes the hair; and the latter the flesh. In the "shave" process only the grain or outside portion is used for leather. The residue is used in making plaster, glue, or fertilizer. After the thinned skins have been "puered" with bran or other substances, they are drenched and worked out on the "beam," to remove all traces of lime salts and other refuse. They are then steeped in vats containing in successive order stronger baths of stringent infusion of sumac, oak bark, japonica, or other tanning agent. During the first few days the skins are handled frequently, to cause the liquor to strike quickly through.

This is often done by paddle-wheels, which turn the skins over and over in the solution, as the more the skins are worked the larger will be the grain of the finished leather.

The tanned skins are then treated to a bath containing a cleansing acid, such as sulphuric or oxalic, when they are "struck out"—a process of stretching out on each side with a tool. When lightly oiled and partly dried they are selected and dyed. The finish is imparted by a coat of logwood, and, after airing in a warm place and draining off, the skins are ready for "wet-graining." They are given a second drying in a warm place, laid away to cool, and seasoned with a concoction of a pint of milk and one and a half pints of blood to a gallon of water, which is rubbed in with a stiff brush. A mixture of milk and water, about one to six, is then applied, and the skins are rolled up, grain to grain. In a few hours they are grained off and treated to warm cod oil, when they are ready for market.

In England and Scotland the usual practice in tanning is to sew two skins together flesh to flesh around the edges, to make the seams tight, and to fill the sacks thus formed with a solution of sumac. This method is said to be cheaper, to give a better color, and requires only one week's time; the other process takes from four to six weeks. Seal leather, when properly prepared from selected skins, is very choice, and has greater strength and durability in proportion to its weight than most other leathers. Because of its soft and pliable texture and attractive grain, it is popular for purses, card-cases, bill-books, shopping-bags, music-rolls, and similar articles. The market value of seal leather is this country varies from twenty to thirty dollars a dozen skins, or about fifty to sixty cents a square foot. Wool-seal, before mentioned, is used exclusively for gloves and trimming.

On the north coast of Norway and Russia walrus hides have been extensively used for rigging vessels, and also to protect certain parts from chafing. In more recent times

they are largely used by silversmiths, cutlers, and other workers in steel goods, for making "buffing-wheels," which are of great importance in polishing metal and horn goods. Because of their tough grain and thickness of an inch or more, the cured and tanned hides are simply cemented on a mandrel, and are ready for use. A side of walrus weighs from one hundred and thirty to two hundred pounds, and is worth from sixty to seventy cents a pound, the thickest part being the most valuable. Some hides are fully two inches in thickness, and silverworkers often pay one dollar to two dollars a pound for selected leather for special purposes. Walrus hides are also used for covering rollers in cotton gins for ginning long-staple cotton, such as Sea Island and Egyptian, as it has been found better than bull-neck leather. About thirty thousand walrus hides are imported into this country annually, at an import value of twenty-five thousand dollars, and a selling value of forty thousand to fifty thousand dollars. The consumption in Europe is about double this quantity; and a suitable hide for polishing purposes is worth in London more than twenty pounds. Hippopotamus-hides are generally classed with the walrus, and are used for much the same purposes.

The proper tanning of walrus-hides requires from six months to a year, but split hides, made thin for various useful articles, are tanned by the same process as seal-skins. It makes a fine pliable leather with a grain that is smooth and velvety, and finds use for nearly, if not all, the purposes to which seal leather is applied. It is very costly, however, and it is confidently stated that fully ninety per cent of the so-called walrus leather is really seal leather that has received the walrus grain in the process of currying. The imitation is so perfectly made that the deception can be detected by very few persons.

The use of alligator leather for useful purposes for which seal leather has long been popular began about 1855, and soon became very fashionable; but after a few

thousand skins had been obtained and shipped from the Gulf States, the demand, for some unaccountable reason, fell off. Toward the close of the Civil War the style was revived, and the slaughter of thousands of sauria annually has been continued to such an extent as to threaten their extinction. In 1869 the decrees of fashion demanded alligator leather for fancy slippers and boots, and even extended to trunks and travelling-bags. Hundreds of men were employed in hunting the reptiles and preparing their skins for shipment to the north for tanning. Large quantities were imported from Mexico and Central America.

Alligator is the most characteristic of all aquatic leathers. Being curiously checkered in irregular oblong divisions, known as "scales" or "bosses," separated by well-defined grooves, and varying in size and character from rough scutes on the back to soft and smooth markings on the under sides, the skin gives a peculiar and distinctive effect desirable for artistic leather goods. There are several varieties of alligator skins, of which Florida, Louisiana, and Mexico furnish distinct kinds for special purposes. The reptiles in the everglades supply the longest skins, cut from the fore to the hind legs, and are generally used for large hand-bags. It is a leather of less value, however, because of the "buttons" or "corn marks"; and farther south these defects become more numerous in the hide, until at Key West the skins are almost worthless. The skins shipped from Louisiana are free of these corn marks, and consequently are more pliable, besides being more artistically curved and shaped. These are used for card cases, pocket books and small articles commanding the highest prices. The skins of South America are much heavier, and are tough and horny and, because of the difficulty of tanning them, are of little value.

Of three hundred thousand alligator-skins produced annually, valued at half a million of dollars, fifty-six per cent are imported from Mexico; twenty-two per cent come from

Florida; twenty per cent from Louisiana; and two per cent from other Gulf States. The quantity of alligators is being rapidly diminished, and it is predicted that, at the rate they are being slaughtered (often for sport, and no use made of them), only a few years will elapse when it will be impossible to obtain the skins at a price to justify their use. The natural supply in Florida and Louisiana is probably less than twenty per cent of that of twenty years ago. None less than five feet in length should be killed, it is contended, if the species is to be perpetuated and the trade in the skins to be continued.

To prevent putrefaction, which sets in so quickly in the torrid climate, the hide is removed soon after killing. A cut is made from the nose to the tip of the tail along either side of the horny ridge on the back, or along the middle of the belly; another cut is made lengthwise along the middle of each of the legs, and a slit around the jaws; then the whole skin is peeled off like a blanket. Much care must be taken in cutting, as the least deviating mark of the knife shows in the tanned and dressed skin. The hide is at once heavily salted with fine-grained salt, rolled up, and stored in as dry and cool a place as possible. When thoroughly cured, the skins are shipped in barrels, boxes, or bags to the Northern States for tanning. The principal tanneries of these skins are in Newark, N. J., and New York City, although some skins are prepared in Massachusetts, and in New Orleans and Jacksonville; and many are exported to England and Germany, and tanned there.

The skins vary from two to seven feet in length, those over ten feet long seldom being tanned, because of the hardness of the hide-plates; yet some as long as seventeen feet have been dressed for use. In the earlier years of the industry only the sides and under part of the hide were used, but as the demand increased in recent times, the back, or "horn alligator," has been made up into articles of trade. The hides are assorted to size, namely, small,

medium, and large, and sold by the length. When tanned, by processes similar to those for tanning seal-skins, they are dressed on a polishing machine, measured, and sold by the width of the leather at the widest part. The price varies from one dollar to one dollar and sixty-five cents for each twelve inches of width.

Chamois, which furnish one of the most valuable of animal leathers, although in very limited numbers, are now the only members of the antelope family found on the continent of Europe. They are small animals, about the size of goats, and seldom weigh more than seventy-five pounds. Their skins, by a peculiar process of preparation, make leather of very fine texture and uniformity of thickness; and in these respects it is superior to all other leathers. Its high cost, however, restricts its use to the making of women's fine gloves, for which doe-skins are also well suited. Chamois leather, strictly speaking, is that part of the pelt which is the under skin, or "flesher," and is secured by splitting the skin through the centre by a machine specially designed for that purpose, and which requires most delicate adjustment. The upper part of the pelt, or "shiver," is used for making thin, fancy leather for book-binding, portfolios, and such articles. It is said that a year's production of genuine chamois, amounting to only about six thousand skins, would hardly meet the demand of the United States for leather of this kind for a single day.

It is the imitations of chamois (and there are many of them, of alum, chrome, and other tannages) that supply the markets in this country and abroad. They are made of sheep and goat skins, and may be distinguished by the peculiar softness and flexibility of oil-dressed skins, and the dark yellow color which is retained after bleaching. As a rule, the finer the wool, the poorer is the skin for tanning; the first and second grades are determined by the firmness of grain and defects in skin. For these reasons and because it is less easily stretched and is more durable,

the imported chamois, so-called, costs about five per cent more than the domestic product. A good oil-dressed skin will absorb moisture very readily, will scour and polish smooth surfaces without scratching, and can be easily cleaned by simply washing in soap and water. When rinsed in soapsuds the skin dries soft with little shrinkage, and when properly used will last a lifetime.

The skin of the animal is removed by a novel and unique method. A hole is made in one of the hind legs, a bellows is inserted, and air blown in, thus swelling the carcass. A cut is then made along the under side from end to end, and the skin carefully stripped off with the aid of a sharp knife. In preparing the skins, the wool is first removed by treating the inside surface to a solution of sodium sulphide (salt and sulphur), or by immersion in milk of lime. The former method requires but a few hours, while the other takes several days. It is afterwards swelled in a lime bath and then cleaned, or "beamed," to remove all fleshy substances adhering to it, when it is split by passing it between rollers against an endless revolving knife. The "flesher" is then sprinkled with codfish oil and evenly distributed and thoroughly incorporated in the skin by much rubbing. After partial drying the process is continued until all pores of the skin are filled, and the moisture dried out. It is then hung in a room with a temperature of one hundred degrees until thoroughly tanned, and the oil is removed by pressure and by saponification. The finishing is done by pressing the skin against revolving wheels covered with emery or flint to remove all particles. It is finally trimmed, sorted, cut to suitable sizes, and packed for shipment. In recent years the skins are trimmed to uniform sizes, and the small pieces are used for making watch pockets and other small articles.

The skins of old goats are hardly suitable for making gloves; when intended for cigar cases, pocket books, purses, and similar articles, they are generally tanned with sumac. Such leather is also used for chest-protectors, vests, and

even underclothing for wear in cold climates. Heavier skins for leggings and mechanics' aprons are oak-tanned; while "bruts" are finished only on one side, to absorb large quantities of water, for use in washing vehicles. Another variety in the larger sizes is double-dressed, for special purposes. Chrome-tanned leather is bluish-gray in color, is very strong, and bears more abuse than oil-tanned skins; and it may be washed with nearly boiling water without injury.

In order to give some very light-straw colored skins a brighter color, they are often bleached when damp by subjecting them in an air-tight room to the fumes of burning sulphur. If this treatment is carried too far, however, some of the sulphur is incorporated in the skin, and it is thereby weakened and unfitted for cleaning silverware, as it is discolored and tarnished. The skins are often colored with aniline dyes to satisfy the demands of trade. A test of skins is to place a few drops of water on the surface; in the case of a good oil-tanned skin this water will be quickly absorbed, while on a poor skin the drops will roll about before soaking in. The American product, which is largely handled by the drug trade, has gradually crowded out the imported skins, and is even getting a foothold in Europe, Germany being perhaps the readiest market. Goat-skins are produced in large quantities in the south of Spain; and in Annonay and Grenoble, France, the making of women's fine gloves from the skins of kids is a large industry. These find a market in the United States, but some of the Spanish goat and kid skins are exported to this country in the raw state for tanning into fine shoe leather.

Rawhide is a form of leather in which the life of the material has been carefully preserved in the process of currying, and is a product of remarkable toughness, tensile strength, pliancy, and durability. It is a most valuable article in the mechanical arts, being extensively used for belting and laces, hydraulic packing, pinions, washers,

harness, mauls, mallets, fly-nets, trunks, saddles, and even artificial limbs. It is very strong, has great weather resisting qualities, and is so supple that when once tightly tied it will hold for a lifetime. For most purposes its cost seems high, but for many uses, such as those mentioned, it is the cheapest article that can be had. The cost runs from ten cents to two dollars and seventy-five cents a foot according to diameter and quality; the most costly, excepting that made to order, is rawhide two and a quarter inches in diameter. One of the most practical uses of rawhide in recent years is for pinions for transmission of power, which replace those made of iron or steel. Rawhide pinions (small cog-wheels) are rigid, hard, and tough, and are almost noiseless, requiring little lubrication.

While the leathers so far described are included in the class of rare and costly skins, but nevertheless of much importance to the trade, the skins which form the staple of our great leather industry are the cow, calf, kid, sheep, lamb, horse, dog, and hog. The skins of all animals suitable for making leather consist chiefly of gelatine, which easily enters into chemical combination with the tannic acid contained in the bark of various kinds of trees, and forms what is termed an insoluble tanno-gelatine. The whole theory of tanning is embraced in this principle; and, while formerly, oak-bark was believed to be the only effective tanning material, a further study of this branch of economic botany resulted in numerous other barks being substituted for that of the oak. Tannin, in fact, is contained in the barks of almost all trees and shrubs, chiefly in the parts nearest the wood; for in the outer coats it is changed by the chemical action of the air. It is not found, however, in poisonous plants, or those that contain elastic, resinous, and milky juices.

"The most important property of tannin is that displayed in its relation to animal gelatine. They combine with much facility,

forming, from a state of solution, a soft, flocculent precipitate, which, on drying, becomes hard and brittle. The combination is not always established in the same proportions, but varies according to the concentration of the solutions and the relative quantities of substances; nor is the compound in all cases insoluble in water. When the gelatine is only slightly in excess, it consists of 54 gelatine and 46 tannin; when there is a large excess of gelatine, the compound is redissolved. On the formation of this combination the art of tanning depends. The skin of the animal, when freed from the hair, epidermis, and cellular fibre, consists chiefly of indurated gelatine. By immersion in the tan liquor, which is an infusion of bark, the combination of the tannin with the organized gelatine, which forms the animal fibre, is slowly established; and the compound of tannin and gelatine not being soluble in water, and not liable to putrefaction, the skin is rendered dense and impermeable, and not subject to the spontaneous change which it would otherwise soon undergo. To render it equal throughout the whole substance of the skin, the action of the tan liquor must be gradual; and hence the tanning is performed by successive immersions of the skin in liquors of different strength.

"Sir H. Davy observes that leather, slowly tanned in weak infusions of bark, appears to be better in quality, being both softer and stronger than when tanned by dense infusions; and he ascribes this to the extractive matter which they imbibe. This principle, therefore, affects the quality of the material employed in tanning; and galls, which contain a great deal of tannin, make a hard leather, and liable to crack, from their deficiency of extractive matter. Hides increase in weight during the process of tanning from one-fifth to one-third."

The application of this principle in treating skins in various parts of this country varies somewhat according to the kind of skins tanned, the tanning agents used (which are usually determined by the economic supplies of the raw materials), and by the purposes to which the leather is used. The processes do not differ materially from those employed for the leathers already described, but the product is in a state like sole leather, and is called "rough

leather." It still requires the currier's art to bring it to the state of completion required for most purposes, and is then termed "dressed leather." When the currier receives the new-tanned skins, they are harsh and stiff, and rough on the flesh side. The roughness is removed by carefully shaving the surface with a peculiar knife. The skin is then soaked in clean water and scraped under pressure upon a tool, called a "slicker," which removes all irregularities. The moisture is pressed out in part, and oil (usually cod oil) and tallow are rubbed over the leather, when it is laid aside to dry. As the remaining moisture gradually evaporates, the oil penetrates the pores and fibres of the leather, and when completely saturated, it is rubbed on a board with rounded edges, to render it very pliable, and to give it the grained appearance. It is the currier's art which gives suppleness and fine finish to leather.

There is another process of tanning in which the compounds of tin are used by causing the colloidal salts of tin to deposit between and in the fibres of the skin. Leather thus tanned is well adapted to most uses, excepting for uppers for boots and shoes. The tanning liquor is a solution of one of the salts of tin, in which the hides are steeped, after having first been treated or cured with common salt for a period of eight hours. The solution of tin is in proportion of one hundred grammes of water to one gramme of tin salt, to which is added a trace of hydrochloric acid. After soaking for two hours, the hides are removed and carefully washed in clean water, and replaced in the bath for two hours longer, when they are again washed and dried. A slight stretching brings out the grain with a fine gloss, and the leather is soft and pliable, and has an attractive finish.

The art of dyeing leather to produce uniformity of color is most difficult, as there are very marked and characteristic differences in the fibrous structure of skins. Some skins are open and loose in texture and absorb

more dye than others which are firmer and more compact, the shade taken being deeper in the former case. The dye acts very differently upon skins which have been tanned with various tanning materials, for the vegetable stuff in the material itself contains some coloring matter, which is imparted to the leather. Thus in a lot of skins in a bath there are always some which take different shades, and it is difficult to give any skin a uniform color, because of insufficient treatment in previous processes. The skins in the dye-bath are turned by hand, one pair at a time; but recently paddles or reels have come into use. These save time and labor, though dyestuff is wasted. Acid colors, especially sulphuric acid and soda, are destructive to leather, as every trace of the acid can never be entirely eliminated. Leather should never be treated with an alkali, or cleared with vitriol or other acid, except acetic acid, which used moderately, has not an injurious effect. Basic dyes are perhaps safer to use where no acid is required to strip the tannage, but they are not so fast as acid dyes.

In waterproofing leather, vegetable or organic fats are employed as a bath, in which it is soaked for eight or more days until it has become thoroughly saturated and will absorb no more. Degras combined with tallow, in the proportion of forty parts of the former to sixty parts of the latter in summer, or equal parts in winter, is considered the best mixture. Another mixture, called "jenning," which consists of equal quantities of soap, zinc, and linseed oil, dissolved at one hundred and six degrees Centigrade, is also effective. Others use thirty grammes of caoutchouc dissolved in a half litre of oil of turpentine as a solution in which to soak the leather to render it impervious to water.

Very little of the cuttings, trimmings, and scraps of the leather industry go to waste in these times of economic conduct of the business, as a process has been employed of pressing the waste pieces into form for decorative

floor cloth and other uses. Waste fibrous material and wax, oil, and albuminous and extractive matter from cottonseed, are reduced to a pulp, then boiled with silicate of soda, precipitated by milk of lime, and the liquor drained off. The waste leather is separately treated with sulphurous acid and thoroughly mixed with the waste pulp and tanning agents or chromium compounds. It is then pressed into any desired shape or form, or into boards, and cut into shoe heels and inner soles. The wastes of tanning likewise find use, even the spent tan and tanning liquors containing lime salts. Scraps and skin are used for making glue; the hair is sold for making cheap blankets and cloth, or for use in lime for plaster; in fact, nothing goes to waste.

The leather industry of the United States comprises (1905, last report) one thousand and forty-nine establishments, and gives employment to more than sixty thousand workers, who earn in a year thirty million five hundred thousand dollars. Some idea of the magnitude and importance of the business may be had from the statement that 108,176,677 hides and skins, valued at $145,467,925, were worked up into leather of different kinds, which had a market value of $252,620,986. One million four hundred and twenty-two thousand six hundred cords of bark, valued at $12,236,801, and other tanning materials, costing $12,793,193 were used, while the currier's supplies amounted to $14,659,841. Fuel, power and heat, and mill supplies, and sundry items aggregated $6,021,313, bringing the total of materials to $191,179,073. The capital employed in the industry at that time was $242,584,254, of which four per cent represented land, twenty-eight and three-tenths per cent represented plant, and sixty-seven and seven-tenths per cent represented hides, tanning materials, and finished stock. The following table is a comprehensive survey of the industry arranged by States in the order of the value of their products:

STATES	Cost of Materials Used	VALUE OF PRODUCTS							
		In Rough	Sole	Upper — Calf and Kid and Other	Other Leather, All Other Products	Goat Skins	Sheep Skins	Harness Leather	Aggregate Value
Pennsylvania	$ 55,411,927	$ 2,298,589	$33,553,676	$ 4,715,006	$ 6,147,071	$19,156,181	$ 567,879	$ 2,989,450	$ 69,427,852
Massachusetts	23,040,897	179,152	429,236	15,321,936	8,244,538	5,277,991	3,900,146		33,352,999
Wisconsin	19,870,887	687,114	4,231,785	12,858,777	1,853,383	7	116,406	6,097,651	25,845,123
New York	16,274,903	836,408	4,977,072	6,724,150	4,137,570	922,035	3,049,763	995,947	21,642,945
New Jersey	15,272,124	873,093		2,404,056	13,907,379	3,161,780	743,802	405,219	21,495,329
Illinois	8,173,788	59,460	585,000	6,417,631	2,464,116		964,099	267,890	10,758,196
Delaware	7,910,779		77,238	119,980	669,573	9,102,297	281,754		10,250,842
Michigan	7,271,023	72,447	4,954,749	1,938,788	1,301,041		218,634	854,690	9,340,349
California	5,912,140	352,799	2,971,579	356,631	2,133,339	12,000	341,262	1,904,647	8,072,257
Ohio	4,462,093	181,347	954,869	895,869	2,607,173	2,500	10,224	1,860,772	6,512,754
West Virginia	4,769,123	311,022	5,270,545	3,618	153,617		458	322,249	6,061,509
Virginia	4,719,206	1,590,818	2,926,054	6,348	1,147,921		28,108	130,563	5,829,812
All Other States.....	18,090,183	2,738,700	8,273,797	1,021,475	6,353,085	252,558	946,294	4,445,110	24,031,019
Total	$191,179,073	$10,180,949	$69,205,600	$52,784,265	$51,119,806	$37,887,349	$11,168,829	$20,274,188	$252,620,986

STATEMENT

In analyzing this table, which throws many interesting sidelights on the industry, the output of sole leather is found to exceed that of any other kind, constituting twenty-seven and four-tenths per cent of the value of all leather manufactured in the United States. Pennsylvania leads all States with an output of fifty-two and eight-tenths per cent of all the sole leather made; West Virginia, New York, Michigan, and Wisconsin, in the order named, are also important producers. This concentration is due to the proximity of oak and hemlock forests, of which the bark of the oak tanned twenty and one-tenth per cent, and that of hemlock fifty-five and four-tenths per cent of all the sole leather produced. The tanning of sole leather is almost a separate industry of itself, as one hundred and forty-nine establishments, employing eleven thousand two hundred and forty-four workers earning $5,411,729 in a year, produced this leather to the value of $64,841,056, or ninety-three and seven-tenths per cent of the aggregate. Pennsylvania also ranks first in the production of rough leather, followed by Virginia, New Jersey, New York, and Wisconsin.

Upper leather, as shown in the figures for the total output, includes calf and kid skins and "all other," of grain, flesh, enamelled or patent finish. Massachusetts is the leading State with a percentage of thirty-two and seven-tenths; with Wisconsin, New York, and Illinois it produced eighty-nine and two-tenths per cent of the total of the United States. The manufacture of patent leather, which it was once thought could not be made successfully in this country, has increased rapidly in the last ten years. Goatskins are largely converted by the chrome process and used for shoe-uppers and gloves. Of this stock eighty-seven and six-tenths per cent was finished black, and twelve and four-tenths per cent colored.

Pennsylvania ranks first, with a production of fifty and one-tenth per cent of the total. Delaware is another large-producing State, followed by Massachusetts and New Jersey. With New York, these five States turned out 45,230,953 skins, valued at $37,620,284, which was practically the total production.

For the output of sheepskins Massachusetts, New York, Illinois, New Jersey, and Pennsylvania, are the leading States. This kind of leather is much better tanned and finished than in former years, and finds use in a wide range of articles from pocketbooks, gloves, and bellows, to cheap grades of shoes, sporting goods, and imitation chamois skins. When dressed with the wool on, it is made into coats, caps, gloves, and sleigh robes. In the production of harness leather Wisconsin leads all States by a large margin; but Pennsylvania, California, and Ohio make this leather to the value of more than a million dollars each. These States, with Kentucky added, produced 2,859,299 sides, valued at $13,927,748, or sixty-eight and seven-tenths per cent of the entire output of the country. It was made in one hundred and ninety-eight establishments, the largest number manufacturing any one kind of leather. The classification, "all other leathers," comprises carriage and furniture leather, kangaroo skins used for shoe uppers, and lambskins, sealskins, alligator-skins, and offal leather. The value of the wool sold was estimated at $2,225,000.

A large proportion of hides are tanned in the commercial centres of the country for economic reasons in order to avoid unnecessary haulage to the manufactories which work up the leather into useful articles. The principal centres of the leather industry are as follows: Philadelphia leads, with an output valued at $23,903,239; Milwaukee, $14,074,397; Newark, N. J., $13,577,719; Wilmington, Del. $10,250,842; Chicago, $9,420,426; Peabody, Mass., $7,919,370; Camden, N. J., $6,364,928.

In value of leather products boots and shoes rank first; the materials and classification of the manufactured goods are shown in the appended table: *

	1905
Materials used, total cost	$197,363,495
Sole leather:	
Pounds	205,142,477
Cost	$44,235,050
Split leather finished:	
Pounds	14,640,317
Cost	$2,679,533
Grain and other side leather:	
Square feet	89,610,877
Cost	$11,805,645
Calfskins:	
Cost	$19,148,411
Goatskins:	
Square feet	197,044,004
Cost	$30,398,403
All other upper leather:	
Square feet	157,205,439
Cost	$27,520,067
Linings and trimmings, all kinds	$10,561,367
Cut soles, counters, taps, heels, etc., purchased	$24,143,824
Findings, purchased	$13,080,280
All other materials	$13,790,515
Products, total value	$320,107,458
Men's boots and shoes:	
Pairs	83,434,322
Value	$142,038,632
Boys' and youths' boots and shoes:	
Pairs	21,717,236
Value	$24,301,298
Women's boots and shoes:	
Pairs	69,470,876
Value	$98,262,016
Misses' and children's boots and shoes:	
Pairs	41,416,967
Value	$34,056,919
Men's, boys', and youths' slippers:	
Pairs	4,403,097
Value	$3,464,561
Women's, misses', and children's slippers:	
Pairs	13,115,194
Value	$10,532,271
All other kinds:	
Pairs	8,552,343
Value	$3,331,690
All other products	$3,327,955
Amount received for work done for others	$792,116
Machinery:	
Boot and shoe machines leased or held under royalties	18,995
Total paid for leases or royalties	$3,343,425

In all the annals of our commercial development and of the expansion of our material resources, it would be

* Census of Manufacturings, No. 57, p. 35.

difficult to find an instance of so great an advance in productive capacity as that of the shoe industry. For more than fifty years after the introduction of the first leather-rolling machine, in 1845, the mechanical development was slow; and the passing of the old-fashioned shoemaker — the old-time cobbler "whipping the cat" at his solitary bench — is scarcely realized in this generation. It presents, however, a most interesting phase of our commercial expansion. Only within the limits of a decade has he of the lapstone, the awl, and the waxed ends disappeared, and in his place has come the modern shoe factory, clean, well lighted, and highly organized.

Within the memory of our fathers the shoemaker took a side of leather, cut out the soles from the thickest part, fashioned the thinner part for the uppers and sewed and nailed them all together on a last. Every process in the making of a pair of boots or shoes was entirely by hand. If he was a skilled and rapid workman a pair of old-time boots was turned out in three days or perhaps a trifle less, and the wearer paid anywhere from eight to twelve dollars for them. Now all that is changed, and the average long-day output of less than one shoe by the old shoemaker has been increased to ten shoes a day for every person employed as a wage-earner in the industry, and the ten shoes are produced far less laboriously and in a far shorter day.

To twentieth-century inventive genius, the consolidation of the makers of shoe machinery, and the rise of the leasing system, is this evolution largely due. Supplanting the little dingy shoe-shop there have risen great factories, filled with wonderful machinery operated by workmen who enjoy the comforts of life, hours of leisure, and social opportunities before unknown. The public are also benefited by this evolution in the making of such important articles of wear, since as good shoes as the old cobbler made, or perhaps better (as machine stitching is more regular than that done by hand), can

UNIV. OF
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MACHINE FOR LEVELLING AND TURNING SOLES

SOLE-CUTTING MACHINE

UNIV. OF
CALIFORNIA

"HEELERS"

BUTTON MACHINE

be purchased anywhere in this country for five or six dollars, while fairly good shoes giving excellent service can be had for three or four dollars a pair.

In the new regime the maker of shoes no longer works from "sun to sun." Machinery, that greatest of boons to mankind, has so increased the capacity of man's hand, that a little group of workmen can by its aid produce in a few hours shoes to a number which the artisan working single-handed could not hope to equal in a year of labor. The shoes so manufactured are comfortable, durable, and possess all the essential features which make a shoe desirable to a degree commercially impossible for workmen using the old-fashioned methods. The excellent footwear of to-day could not be produced without the aid of machinery, except at great increase in cost; for the genius of the inventor has set aside the old-time slow and laborious methods of manufacture; and, as a result, even those in the most moderate circumstances secure all the comforts and satisfaction in shoes which but a few short years ago were denied to all but the wealthy.

Every detail of the method employed in making shoes by the latest welt process was made known to the visitor in the model factory of a great shoemaking company. Every machine throughout the seven floors of the main building and the annex adds something — it 's a mite, perhaps — to the comfort, durability, and appearance of the well-made shoe; and shoes made by the welt process are universally acknowledged to be without a peer in all the qualities that make a shoe desirable. Because a shoe is made either a comfort or a torture in the manufacturing process, the details affecting its construction are of the utmost interest; and even a superficial observation of a day's study of the factory methods discloses marvels of late-day machinery never dreamed of by the most visionary of the old cobblers.

In the beginning of shoemaking the parts forming the

upper portion of the shoe are cut to conform to certain patterns, which are fashioned from approved designs by regular pattern-makers. These men are kept busy cutting thousands upon thousands of thin metal sheets into various shapes and sizes. For every new style of shoe put on the market, about sixteen thousand patterns of wafer thinness must be made, of all sizes; for in these days of quarter-sizes there are many cutters to be supplied in keeping up to the capacity of the factory. The linings are also cut from a special cloth, and the different parts are taken to the big stitching-room.

Passing along in front of the counters in the stock room, clerks may be seen checking out sides of leather to the cutters, of the kind and grade called for by the specifications on their order cards. One cutter receives sides of patent calf, another gets vici kid, while still others take away heavy calf stock. The demands of trade require that shoe stocks shall be made months in advance of actual needs; thus, winter shoes are made in the summer and fall; light shoes, oxfords, and slippers are turned out in winter and spring. A little farther on these cutters may be seen busy with the bright, clean leather and their proper patterns. They place a pattern on the flat surface of the leather and with nimble fingers follow the outline with a keen-edged knife, and in a twinkling the job is done. Each lot, cut according to the order card, is strapped together and passed on to the stitching-room.

In this department the edges of the parts that form the shoe-upper are skived and bevelled on a machine called the skiving-machine. This little device performs the work with rapidity, following the contour of the different pieces with exactness. These edges are then folded by a small machine so that they present a finished appearance. The ornamentations which are generally shown in a series of perforations in the toe-tip are then died out from the leather by the power tip-press, which

performs its work with surprising rapidity. The different parts of the shoe are then sewed together by power sewing-machines, girls and women being the operators. The uppers are passed on to others operating eyelet-machines, which place the hooks and eyes with a precision and a speed that are astonishing. The matter of "fast color" eyelets is important. Cutting in two an eyelet of the kind being used for the better sort of footwear, we found it to have a composition top, while the barrel, the part that is clinched inside the shoe-upper, was of brass, nickel-plated to prevent corrosion. It is impossible for this kind of eyelet ever to wear "brassy," an effect that cheapens the appearance of shoes.

The preparation of the different parts that are to form the sole of the shoe now receives attention. On the other side of the second floor is a heavy stamping-machine, which cuts the outer soles from either thick or thin leather by one downward stroke of its die-head. The dies are made the exact shape of the sole, but a trifle larger than the size of the shoe for which they are intended. With the proper leather placed directly beneath, every stroke produces a perfectly shaped sole. It is interesting to see a hundred or more soles stamped out in a minute. The inner sole is also roughly died out and reduced to the desired shape on a sole-rounding machine; then it is passed through a little machine which brings it to an absolutely even thickness. In this way all the insoles and outsoles are reduced to uniform thickness, so that each is the counterpart of the other in this particular regard.

The outsole is then passed to a heavy rolling-machine, where it is subjected to tons of pressure between heavy rolls. This takes the place of the hammering which the old-time shoemaker gave his leather, and brings the fibres very close together, greatly increasing the durability. The insole also receives further preparation. It is channelled on a special machine, which cuts a little

slit along the edge of the insole, extending about one-half of an inch toward its centre; it also cuts another narrow channel along the surface. The little lip which has been formed is then turned on another machine, so that it extends out at a right angle from the insole, forming the shoulder against which the welt is sewed. The heels are also formed from different lifts of leather, which are cemented together. The heel is then placed under great pressure, giving it exact form and greatly increasing its durableness.

These different parts of the shoe now come together in the "making-room." A wonderfully ingenious machine, the Ensign lacing machine, passes a strong twine through the eyelets in a twinkling, and ties it automatically. This is done so that all parts of the shoe-upper will be held in their normal positions while the shoe is being made. The workman takes the shoe-upper, puts in place the toe-stiffener, also the counter, which are cemented in their proper places. He also tacks to the bottom of the last the insole, which conforms exactly to its shape. This last is made of wood, and is most important, for upon its form depends the shape of the shoe. The workman places the last inside the shoe-upper and puts it on a spindle of the Rex assembling-machine, sees that the seam at the heel is properly located, presses a foot lever, and a small tack is driven part way to hold it in place. He then hands it to the operator of the pulling-over machine. This machine is a very important one, for, as the parts of the shoe-upper have been cut to conform exactly to the shape of the last, it is necessary that they should be correctly placed on the last to secure the desired results. The pincers of this machine grasp the leather at different points, and the operator, standing in a position from which he can see when the upper is exactly centred on the last, adjusts the machine. When that has been done, simply pressing the foot lever starts the machine in operation, and the

leather is drawn around the last and securely tacked in position in a second of time.

The shoe is then ready for the lasting machine. This is one of the most difficult and important parts of the shoe-making process, for upon the success of this operation depends, in a great measure, the beauty and comfort of the shoe. The hand method welt-lasting machine which is used for this purpose, takes its name from the almost human way in which it performs its part of the work. It draws the leather evenly and tightly around the last; at each pull of the pincers a small tack, driven automatically, only part way in, holds the edge of the upper exactly in place, so that in the finished shoe every part of the upper has been stretched in all directions equally. A trimming-machine rapidly trims off any surplus parts of the upper; and the Rex pounder, in which there is a little hammer, pounds the leather and counter at the heel, so that this stiff portion of the shoe conforms exactly to the shape of the last.

The shoe is then ready to receive the welt, which is a narrow strip of carefully prepared leather that is sewed along the edge of the shoe, beginning where the heel is placed and ending in the same place on the opposite edge. The welt is sewed from inside the lip of the insole, so that the needle passes through the lip, uniting all three together, allowing the welt to protrude beyond the edge of the shoe. This part of the work was formerly one of the most difficult and laborious tasks in shoemaking, as it was performed entirely by hand, the drawing of each stitch depending on the strength and mood of the workman. It was noticeable how easily and quickly the work was performed by this wonderful machine, which has been a leading factor in the great revolution that has taken place in shoe-manufacturing. In its working, every stitch is of equal length and measured automatically, the strong linen thread, thoroughly waxed, drawn evenly and tightly, for the machine never

tires; it draws the thread as strongly in the afternoon as in the morning, a trait which is hardly true in the human artisan.

As the lasting tacks were drawn just prior to this operation, the inside of the shoe is left perfectly smooth. After this process the surplus portions of the lip, upper, and welt are trimmed off by an inseam trimming machine, and the welt is made to stand out evenly by a welt-beater. The tacks which held the insole in place are now removed; and the outsole, which has previously been coated with rubber cement, is pressed securely in position by the sole-laying machine.

So many machines of curious construction and widely different sizes, all contributing their share to the whirl and rumble of the big factory, were rather confusing to the casual visitor. But when he was told that every shoe passes through more than a hundred distinct processes, and as many machines, and that one hundred and forty-six operators handle the shoe from the leather to the packing and labelling of the shipping-case, he began to realize that this is an era of small mechanical units, working in harmony and with perfect system to produce the finished whole.

The next operation is that of trimming the sole and the welt so that they protrude a uniform distance. This work is performed on a rough rounding-machine, which gauges the distance exactly from the edge of the last. By the use of this remarkable machine the operator is enabled to make the sole conform exactly to all others of similar design and size. The machine at the same time cuts a little channel in the sole in much the same manner that the work was done on the insole. This portion of the work was formerly a very difficult and costly operation by hand, but seems simplicity itself as shown in the use of this machine.

The channel-opening machine then turns up the lip of the channel and the sole is ready to be stitched to the

welt. This is done on the rapid stitcher, which unites the sole and welt with a tightly drawn lock-stitch with remarkable strength. The following operation is done on a cementing-machine, which is provided with a rotary brush that carries rubber cement and thoroughly coats the little cut which has been made in the edge of the outsole. The operator presses it against the wheel of the channel-layer, brushing it smoothly down, so that the stitches are entirely hidden when one is looking at the bottom of the sole.

The shoe is then ready for the automatic sole-leveller, which is one of the most interesting machines in the shoemaking process. How carefully it rolls every part of the sole! There can be no unevenness in the sole-bottom after this operation, for it is under heavy pressure throughout. That portion of the sole which comes against the heel has not yet been united to the shoe, as the work of the welt-sewing machine began and ended at a point where the heel is nailed in place. It is, therefore, nailed to the shoe on the loose nailing-machine, the nails being driven through the outsole and insole and clinched inside the shoe against a steel plate on the last. This machine drives separate nails, of any desired size or length, at the rate of 350 a minute, placing them at the will of the operator. The portion of the outsole which extends around the heel is now trimmed to conform exactly to the shape of the heel, on a machine specially designed for the purpose.

The shoe now receives its heel, which, with the exception of the top lift, has already been prepared as previously described. The heel is secured in place by the American lightning heeling-machine, and it does the work rapidly and with precision. The shoe is placed on a jack, and the heel nails, which have already been stuck in the holes of a steel plate representing the form of the heel, are swung into position exactly over the heel, dropping automatically into another plate, and on pressure

of a foot lever by the operator, all are driven by the machine at one time through the heel, upper, and insole, and clinched back into the leather. The nails are left protruding slightly above the heel so as to retain the top lift, which is now placed in position; then the operator again pressing the foot lever, forces it down over the heads of the nails, securing it in position. The small brass or steel pieces, which protect and ornament the heel, are now driven. They are called "slugs" in the vernacular of the shop, and the machine that does it the slugging-machine. The surface of the top lift is now made perfectly smooth and even by a sanding machine, and the edges of the heel are made smooth and even on the heel-scouring machine. This has two rapidly revolving rolls, on which the sandpaper is made to conform to the shape of the heel, grinding away all unevenness, while blowers carry away all dust resulting from the operation.

The breast of the heel, or that part which faces toward the forepart of the shoe, is trimmed off evenly and smoothly by a breasting-machine, which is provided with adjustments that make it possible to force the knife through the various lifts of the leather with one clean thrust, cutting to the exact point at which the heel is joined to the outsole of the shoe, without cutting into it. The heel breast-scouring machine, on which are little discs covered with sandpaper revolving very rapidly, now smooths this part of the heel and the shoe is ready to have the edges or the forepart trimmed. This work is done on the edge-trimming machine, in which a little wheel made up of a series of blades revolving very rapidly trims the edges of both forepart and the shank evenly and rapidly. The edges are then coated with special blacking, and the stitches are made to stand out individually where they show on the welt, by the separating machine, a little tool making a series of indentations between the stitches, giving them an even and

pleasing appearance. The edges are set or finished on a special machine in which a small and constantly heated piece of steel is passed over the edge with a peculiar rubbing motion, which brings it to a brilliant and lasting finish. Any surplus ink or dust that may have gathered on this particular part of the shoe is removed by a cleaning machine, on which two rapidly revolving brushes do the work.

The heel is finished by being coated with a special ink and pressed against the heated wheel having a number of segments lying diagonally across its surface, which conform to the shape of the heel. A little disc carries to the wheel a peculiar wax in a hot state, and the wheel beats it into the heel so that, after the heel is treated on a rapidly revolving brush (also on this machine) it presents a perfectly smooth surface of unusual brilliancy, and this finish is lasting.

For the final operations the stains on the sole acquired in the various operations are removed by a machine having two sandpaper-covered rolls, which do the work with surprising rapidity. But this buffing does not do all that is desired, so a buffer of an entirely different type is used. In this machine a little pad of rubber, covered with fine emery paper revolves about seven thousand times a minute; that is, of course, sufficiently rapid to burn anything that comes in contact with it, under ordinary circumstances, but the little rubber pad is distended with a constantly renewed pressure of air from an air pump, which is a part of the machine. This combination gives the sole and shank a beautiful, velvety appearance and makes possible the most desirable bottom finish. The bottom is blacked or stained and brought to a high gloss by the various brushes on a finishing shaft, which revolves very rapidly.

In order that the quality of the shoes may be recognized, the manufacturer now desires to place his name or trade mark on the bottom of the sole or the shank.

This work is done by a stamping machine, whereby an operator is enabled to press the heated die against the bottom of the sole under any pressure that he may desire, from one to ten thousand pounds. The last over which the shoe had been drawn early in the making has been kept in place through all these operations, so that the finished shoe would acquire exactly the desired shape and retain it. It is now drawn from the shoe, which is placed over the form of a treeing-machine; and the operator pressing a small foot lever, causes the form to expand inside the shoe into exactly the shape of the original last, while the operator smooths out every semblance of a wrinkle with a special device of steel. The form is made to contract inside the shoe, which is removed without disturbing a line of its beautiful finish. Three little creases are then made in the vamp of the shoe, where the breaks occur when the foot is bent, for the purpose of causing the creases formed in wear to assume more regular lines and thereby greatly increase the beauty and durableness of the shoe. After a final brush, to remove every particle of dust, laces are inserted, and the shoes are then ready for inspection.

In this section the visitor will be amazed at the great array of styles and sizes of shoes being carefully examined for the least flaw or scratch, and also the number of odd shoes made to fill special orders. A fastidious maiden lady living in Oshkosh, with a swelled purse, must have a certain leather with a definite finish for her shoes; a slight young girl in Chicago can never get shoes narrow enough to suit her; an old customer out in Idaho must have special shoes because a pet bunion precludes the use of any shoe not made to ease it; while still another from somewhere in Texas wants an extra wide shoe to accommodate the gout. And so it goes, supplying the special needs of dealers all over the country and aiding them to build up their business in the separate communities.

The capacity of one of the largest factories is eight thousand pairs of shoes a day; two thousand skilled artisans and workmen are employed in the two large buildings; and their field of operations knows no limitations. The weekly pay-roll exceeds twenty-five thousand dollars. There are fourteen hundred machines of different kinds in the two factories, using five thousand miles of silk thread yearly. The lumber used in making packing-cases each year amounts to one million four hundred thousand feet, board measure. The lasts number three hundred and twenty thousand, the patterns used last year about sixty thousand. The hides from two hundred and eighty cattle are used for sole leather each day, while the skins of fully six hundred thousand animals are used in a year to supply leather for these shoes. And this represents the activities of only one manufacturing unit in one branch of the great leather goods industry.

It has been well said that "the history of industrial progress is the history of increased efficiency in production." Increased efficiency comes about by the application of improved methods, by coöperation, by the use of mechanical devices, by which individuals or sets of individuals are able to produce to-day more goods and of more uniform excellence than they laboriously produced yesterday. In this there have happened three things of economic advantage to the fabric of our commercial development: "A foundation has been laid for a general increase of material wealth; the individual has been lifted and his horizon broadened; and, coincidently, the door has opened for an infinitude of complexities, practical, social, and even political, unthought of while the workers toiled alone and with their hands." The leasing system of shoe machinery, although severely condemned by persons who prefer the abstract to the laboratory method of discussion, is an excellent example of high specialization and modern centralization of capital and industry for public policy.

The present high efficiency of modern shoe-factories is largely due to the perfection of the system of machinery leases, the beginning of which was coincident with the introduction of the McKay sewing-machine, in 1860. Ten years before, a machine had been produced for driving pegs as a fastening for soles, and in a short time boots and shoes made in this way were exhibited and sold to the public. This marked the beginning of the shop system whereby shoemakers worked together; but it was the McKay machine, which sewed the soles and uppers together, that inaugurated the factory system by which the most laborious processes of shoemaking were accomplished by machinery. The edge-trimming machine, the edge-setter, and the heel-burnisher came in 1865; and in the early seventies machines for fastening soles with metal screws and wire, and for making and attaching heels, were introduced. In 1877 the Goodyear welt-and-turn machine, and a few years later the outsole stitching-machine, were brought out and heralded as most important advances in high-grade shoe machinery. The improved machines imitate, and now actually improve upon, the older hand-work method of first sewing a welt strip to the inner sole and then sewing this welt to the outsole on the edge. The "pulling-over and lasting" of the shoe by a mechanical device was first accomplished in 1875, but it was a number of years before the full operation was performed by the machines without the aid of the workman.

It is interesting to note the effect of improved machinery and economic methods upon the skilled workmen engaged in this great industry. To-day shoe factories are divided into different departments, each having its appropriate machines for a definite part of shoemaking. In one, as has been shown, the upper leather and linings are cut; in another they are stitched, and the eyelets or buttons put on; then, there is the outer and inner sole-cutting department, and the bottoming department where

the soles and uppers are assembled and fastened together; and finally, the finishing department completes the long process. These are separate and distinct processes to the extent that the workers do not mingle, nor do the different branches affiliate in the same unions. There is a lasters' union, an edge-trimmers' union, a cutters' union, and so on through the list of distinct operations.

Although the leasing system had its beginning fifty years ago, with the placing of the McKay machine in the small shoe-factories of the time on a royalty basis, the perfection and extension of the system to effect economic results has been a development of only the last ten years. For many years, in addition to the royalties exacted on the number of pairs of shoes produced by the use of the machines, there was required a large initial payment from the shoe manufacturers, amounting in some cases to ten thousand dollars. Since the consolidation of the principal shoe-machinery companies, these initial payments on the machines have been practically abolished, so that now the leases are on a purely royalty basis. The old principle has, indeed, been reversed, since the shoe-machinery manufacturing corporation now actually gives bonuses, or rebates, to those of the shoe manufacturers using its machines who adhere to the spirit and letter of their leases. Moreover, it is said that the rentals or royalties now charged are no higher, but in some cases are lower, than exacted under the old regime. In fact the relations between the shoe manufacturers and the makers of shoe machinery are peculiarly intimate.

In 1899 the consolidation of the principal manufacturers of shoe machinery was effected without the intervention of promoters, and without any profit to anyone, except that which came from enhanced value of the stock by means of the consolidation. Improvements were made available for nearly all shoe machinery, great economies were instituted, more workmen were employed in the machine shops, and more agents and repair men

found work in the branch establishments in all shoe manufacturing centres, to keep the machines in perfect running order. All shoe manufacturers, both small and large, are operating the machinery on precisely the same terms of agreement and royalty, which should encourage the establishment of new factories in or near large commercial centres. And it is asserted that improvements of machinery have advanced more rapidly since the consolidation than in any period of ten years before that time.

The aggregate of the royalties paid is an enormous sum, but when reduced to the amount paid on a single pair of shoes, and which the wearer of course pays, it is insignificant, and can not be a burden to any one. The largest proportion of shoes manufactured are of a quality to retail at two dollars a pair; those sold at two dollars and fifty cents are the next largest quantity; and the production of shoes at three dollars and fifty cents and four dollars a pair is considerable. The royalty paid by the shoe-manufacturer to the shoe-machinery corporation amounts to from three to six cents a pair. While this tribute to the corporation would at first thought seem to come out of the profit on the shoes, it scarcely works out that way in practice. As a first consideration the shoe-manufacturer is relieved of an immense initial investment for machinery, and the consequent interest charge on that investment, which is of course, a part of the cost of production. The royalty offsets this, and should be considered a legitimate expense. It hits the wearer very indirectly, as it is not added to the price of the shoes he wears; but, if the manufacturer is bent on his paying the tax (and this is true in the case of cheap shoes), it is taken out somewhere in the manufacturing process or in the quality of the materials, and further cheapens the product. But when it is considered that really good shoes, better than the old cobbler ever made, can be had for four dollars a pair, as against two or three times

the amount paid under the old system, the leasing system of shoe machinery seems to be a boon to mankind.

The increase of material wealth, as shown in the value of the product, is indicated by comparative reports, that of 1905 (last report) amounting to $320,107,458; in 1900 it was $261,028,580; $220,649,358 in 1890; $166,050,354 in 1880, and $91,889,298 in 1860. The condition of the wage-earner has correspondingly improved. In 1860 his average yearly income was $246; in 1880 it had increased to $399; in 1900 it was $412; in 1905 it had reached $461. Besides this, he now has a far shorter day, numerous holidays, highly developed unionism, and other benefits to himself as his leisure and opportunities multiply. It may be added that, with all the changes that have taken place including the great advance in the price of all leather and other materials, the shoe-manufacturers of the United States were never so prosperous as they are to-day.

The kid-glove industry is of ancient and doubtful origin, but it is probable that the town of Grenoble, in France, may rightly claim the distinction of being the first community to produce fine kid gloves on a commercial scale. The town lies in the centre of the region surrounded by mountains, furnishing the finest kid skin, and where the cheap labor of peasant women can be economically employed for hand sewing. Although the quantity of gloves produced by the hand method was small, the town won a reputation for quality several centuries ago. As long ago as 1691 a glove corporation was formed, and records of production and prices were kept. In other places the skins obtained are smaller and less elastic, which is due to the animals being less carefully nurtured; for poverty of the soil is a direct cause of inferiority of skins. Where pasturage is good the grain of animal skins will be fine, thin, strong, and generally free from scars and disease. Further south the dry pasturages and hot climate conduce to poverty of

condition and to inferiority of skins. Careless methods of removing the skins often cause damage, and indifferent preparation renders them unfit for glove-making; and poor skins are used only for lining boots and shoes. Since the invention of sewing-machines the industry has gradually become decentralized, and kid gloves are now made in nearly every civilized land.

The industry was started in America about 1790, and has been of commercial importance for nearly a century. Sir William Johnson, special agent of King George to the North American Indians, brought over from Scotland a number of glove-makers and their families, together with patterns and supplies of needles and thread; and the first gloves made on this continent were used by farmers and wood choppers. The Indian process of tanning was followed, by which the brains of the deer insured a durable and pliant leather. The brain of the hog was sometimes substituted, but the leather thus tanned was less desirable.

The present methods of tanning fine leathers are so similar that only in the agents and concoctions used do they differ, and need not be repeated here. The leather from the tannery goes to the cutters, who lay it out on blocks or tables and cut out the pieces according to the numerous shapes and sizes of the patterns. Blocks are used for the cheaper and coarser grades, while tables are the most convenient for thin, fine leather. In the former case the sharp edge of the die is placed over the sheet of leather and struck with a maul, but for thin leather, a sharp knife run dexterously around the pattern cuts it out perfectly. The skin is first dampened and stretched over the ends of the table until it will give no more, it is then cut to length, stretched as to width, and cut to width of the glove to be made. The finger and thumb openings are put in with die and press. Gloves so made are more elastic, and conform to the shape of the hand much better than block-cut gloves of heavier

quality, but in the cheaper gloves fit is not essential. The table cutters in the United States are for the most part of French, German, and Swedish nationality, but even with all their skill, only one workman in three, it is said, is an excellent and expert artisan. Good judgment is required in examining the skins to get from them the most gloves without flaws, and nimbleness of fingers is essential for rapid and accurate work.

From the cutters' room the trimmed leather is sent to another department, that of the "silkers," who embroider the back; and from there it goes to the "makers," who sew the fingers and put in the thumbs. Other workers are called "welters," who hem the edge around the wrist; "pointers," who work ornamental lines on back. The glove is closed by beginning either at upper end of long seam and sewing toward the little finger, or at the end of the under finger and finishing with the long seam. The glove is then bound, hemmed, or banded, the button holes are made, buttons are sewed on, or lacings attached, or fasteners put in, as the case may be. It is finally drawn over metal hands heated by steam, a "laying-off" process, by which it is shaped and given a finished appearance. In 1900 the capital invested in land, buildings, and machinery in the industry, comprising three hundred and ninety-seven factories, was nine million dollars, and the value of the product was seventeen million dollars, an increase of sixty-eight and seven-tenths per cent during the ten-year period.

In these days there are large quantities of cheap leather splendidly finished and to all appearances of good quality, but which owes its high finish to the use of tanning materials and treatment injurious to its strength and life. It is to be regretted that such leather is so largely used for fine bindings of books. Very often the treatment that good skins receive in tanning, in shaving, in stretching, and in dyeing and finishing, as well as in the processes of bookbinding, is such as to weaken the fibres

of the leather and to cause their rapid decay. Mineral acids used in dyeing are destructive, and too strong tannages often produce in Persian morocco and sheep signs of decay in one year. Librarians have discovered that leather tanned with gambier, larch, quebracho, hemlock, and turwar, are particularly liable to decay; while leather tanned with a light infusion of sumac or oak bark, remains in almost perfect condition for a hundred years or more.

It is quite evident that the tanners of to-day could profitably follow the tanning methods of three or four centuries ago, primitive though they were, since there still remain in very good condition bookbindings known to be very old, and which give reason to believe that they will be serviceable for many years to come. In the old days light tannages were the rule, and plenty of time was allowed for proper tanning, all of which is quite the reverse to-day, when so-called scientific tanning agents, which make leather quickly, are universally used, although entirely unsuitable for bookbinding leather. It is scarcely possible that any change has taken place in the nature of the raw skins, hence it is generally taken for granted that the causes of decay must be looked for in the modern processes of leather manufacture. For one thing, modern bookbindings are thinner than of old; and microscopic examination shows that the fibres of the old leather are in an upright condition, which is not the case with modern leather. The stretching and tight-setting out of the skin lays the fibres flat and parallel. Leather tanned with sumac, which has stood the test of time, is least affected by the fumes of burnt gas, artificial light, direct sunlight, or moist and very dry air.

Many books supposed to be bound in levant morocco, hard-grained morocco, pigskin, calfskin, crocodile, and alligator leathers, were found upon close examination to be covered with common sheepskin. The deception was skilfully carried out by electrotype rollers, special grains

and characteristic markings of skins, which they imitate, being made so as to defy detection. This is due to the cheapness of bookbinding, a state the art has reached within the last twenty years. The average person will not pay the price for genuine fine leather of great durability, and cheap and unreliable leather is thus substituted by the bookbinder from necessity. The economic balance in bookbinding would probably be attained by specifying that pure sumac tannage of proper strength be used in tanning really good skins of fine grain; no mineral oil of any kind be used in any process; that proper length of tanning be given; and that the skins must not be pared down to paper thinness. Then, with intelligent and careful binding book covers should be as durable as those which have stood the tooth of time, even from the fifteenth and sixteenth centuries.

VII

MOULDING

MOULDING-MACHINE PRACTICE

IMPROVEMENT IN MOULDING-MACHINES — THE SAND-MATCH — THE MATCH-PLATE — THE STRIPPING-PLATE — THE ROCKOVER MACHINE — THE KILLING STRAIGHT-DROP MACHINE — THE ROLLOVER STRAIGHT-DRAW MACHINE — POWER RAMMERS OF VARIOUS KINDS — TABOR MOULDING-MACHINES — MULTIPLE-MOULDING MACHINE — THE RATHBONE MACHINE — SAVING EFFECTED BY IT — GRAVITY MOULDING — THE FIRST AUTOMATIC MOULDING-MACHINE.

THE history of the art of moulding and the casting of metals dates back hundreds of years. Even the idea of the multiple mould is not new; it is probable that credit for its inception is due to the Chinese. Moulding-machines have been used much longer than is generally supposed, but it is only during the past twelve or fifteen years that they have become universal in the best foundry practice. Twenty years ago a machine that would take in flasks up to thirty-six inches, round or square, was considered an exceptionally large one. To-day there are machines that will take flasks up to seven or eight feet in diameter, and in the square type up to eight feet width by twelve or fourteen feet in length.

The primary object of all moulding-machines is to reduce the cost of castings, and, although this is effected by increasing the output per man and employing cheaper labor, the secondary object — to obtain better castings — is also accomplished. As a result of smoother and truer castings there is a further saving in the cost of finishing, either in the clipping-room or the machine shop, or both.

Machines so constructed as to require the services of skilled mechanics to install them and afterwards to keep

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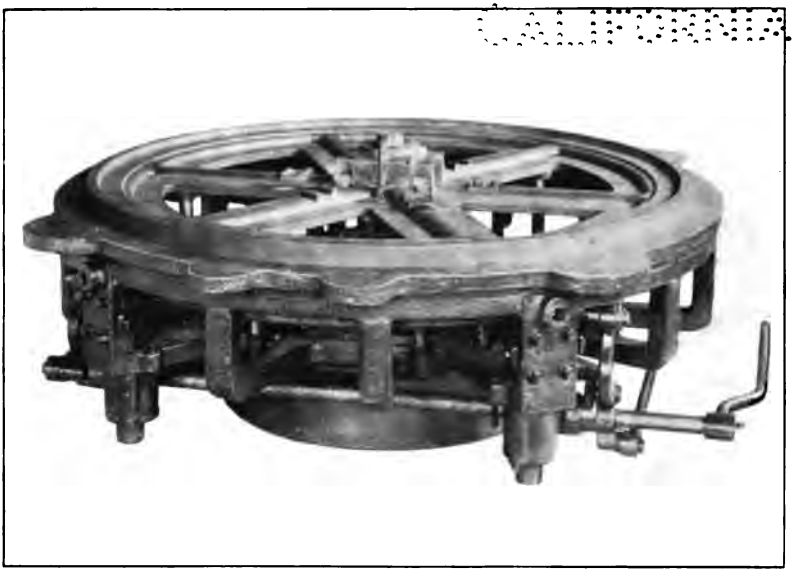
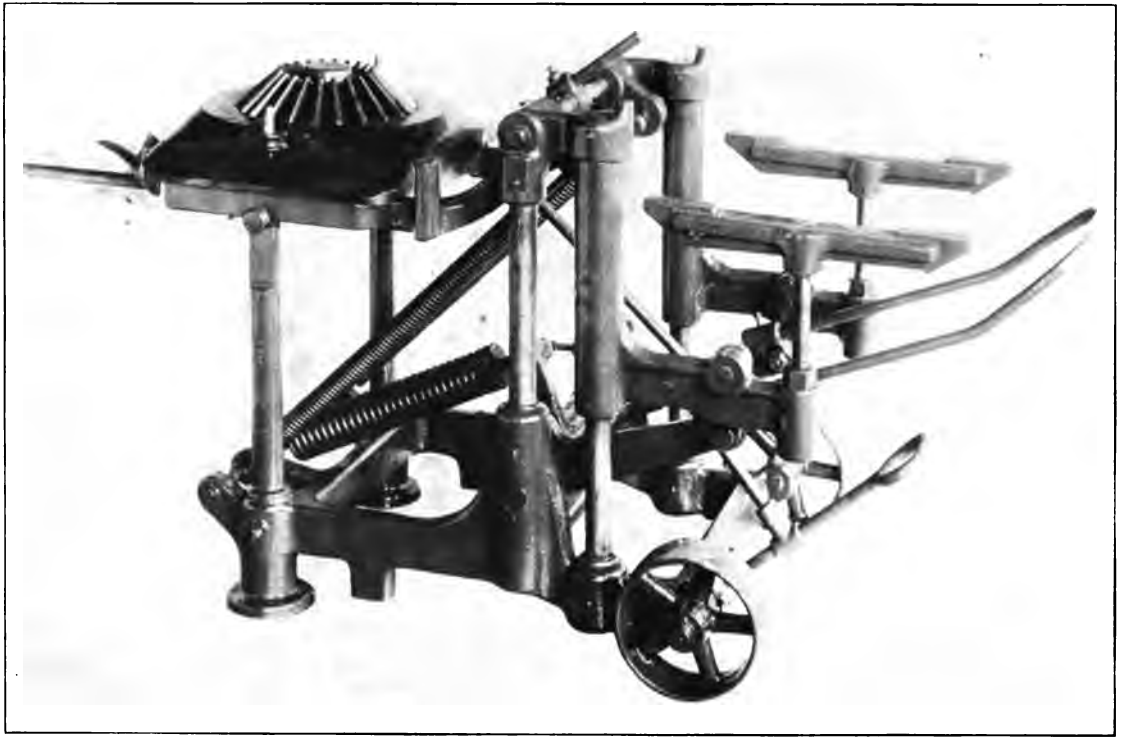


ROUND MOULDING MACHINE, FITTED WITH FLY-WHEEL PATTERN

MOULDING MACHINE, FITTED WITH GAS OVEN BURNER PATTERNS



ROCK-OVER DROP MOULDING MACHINE

them in running order, are unsuited for the work that is required of foundry equipments, which necessarily are subjected to the roughest usage. It is evident, therefore, that a moulding-machine, to be of practical utility and a money-maker, must combine the prime qualities of simplicity and speed. It must not only be of durable and simple construction to be successfully operated by a workman of ordinary intelligence, but its operation must entail the least effort on the part of the worker in order to obtain the desired speed. Furthermore, to produce castings of a high and uniform excellence, the moulds must be far better than are usually made by hand methods; and to accomplish this the moulding-machine must be positive in action — in the ramming of the sand and in the drawing of the patterns.

Probably the most elementary moulding-machine is the sand-match, which relieves the necessity of making a parting by hand, and is extensively used to-day, but is supplemented for large work by the follow-board, which answers the same purpose and is more durable. The match-plate, which followed, was universally a flat plate of either metal or wood, but in the course of development it was found expedient to use cast match-plates with irregular partings. This was accomplished by making a mould from a master pattern which allowed for two shrinkages. Then, after closing up the mould, parallel cores ranging from one-fourth to three-fourths of an inch in thickness, according to the requirements, were laid around the flask joints, thus giving, when poured, a plate with half a pattern on either side. If the flask pins were accurate for a length greater than the thickness of the plate, an absolutely perfect match was assured.

The next step logically from the match-plate was the stripping-plate, which primarily was a match-plate, but to which the pattern was not attached. The earlier types of these machines consisted of two plates, the upper one being cut to the exact outline of the pattern, while the

lower plate had the pattern attached to it, a spacing-plate the thickness of the stripping-plate being placed between them. In the operation the stripping-plate makes the parting, the pattern being drawn through it by lifting off the plate with the mould, leaving the pattern attached to the plate below. From this elementary device it was a simple move to employ mechanical working parts to effect the drawing of the pattern. And there is at once the stripping-plate machine of to-day.

Perfected stripping-plate machines insure a perfect drawing of the patterns, dispensing with the rapping or vibrating of them, and furthermore, they save the expense of patching the moulds, and permit the use of a less skilled class of labor, while producing more uniform and nearly perfect castings. With all these advantages, however, they in no way reduce the labor of shovelling or ramming the sand. For large work there can be no question about stripping-plates being the most effective type. Patterns may be drawn from the sand by their use which have absolutely no draft, and a grade of castings may be produced which would not have been thought possible before their introduction. For such work as large boiler sections, gears, flywheels, pumps, cylinders, and so forth, stripping-plate machines have not been surpassed.

The castings made in a large flask, thirty-six by forty-eight inches, and the pattern used, a boiler section, when moulded on the floor, cost about two dollars each. On the improved machine the same castings can be made for eighty-five cents. A small pattern using a ten by sixteen inch flask fitted for moulding gas-oven burners, four patterns in a flask, when operated by hand, will produce thirty flasks for a day's work. From the small stand machine used on the job ninety flasks can be obtained in the same time, thus trebling the output. There is a Pridmore, sixty-four inch round, double-shaft machine fitted for moulding flywheels, which has reduced the cost

of castings from three dollars and eighty-five cents, as made on the floor, to one dollar and twenty-nine cents each.

While experts do not as a rule advocate the use of machines for moulding where only one or two pieces are required, some concerns use stripping-plate machines for making two or three moulds of a kind. This practice has been greatly increased in the last two or three years by the introduction of rockover drop machines of the Pridmore manufacture. The rockover machine is of great service in rolling over the drag half of the mould. The drag pattern is attached to a match-plate on the frame of the machine, so that, after rolling over, if the pattern has ample draft, the flask may be detached from the match-plate by being vertically lowered away from the pattern. This insures a perfect drag pattern on any work that has ample draft. For making the cope half of the mould, the rockover machine is not so efficient, for it leaves the mould upside down. For a very large class of work, such as furnace fire-pots, the most economical results are obtained by a combination of the rockover drop for the drag pattern and the stripping-plate for the cope. These machines are designed also for the production of castings of medium sizes having deep pockets which, in the moulds, form hanging portions of sand.

In operating these machines the flask is set on the plate with which the pattern is fitted. The flask is then filled with sand, rammed, and covered with a bottom board, which is clamped on by throwing over a rod pivoted on a common centre with the plate. The operator then grasps both the rod and the plate-handle and throws the plate, the flask, and the rod over to the other side of the machine, where the flask and bottom board rest upon a stand, which has been previously adjusted to the depth of the flasks in use. The drop-lever is then forced downward, in which operation the flask and mould are carefully lowered away from the pattern, the flask separating

easily from the pattern plate. This feature represents the advance over previous rockover machines, and results in an absolutely perfect mould, having sharp, clear edges. The plate, with its pattern, is then thrown back to its original position, and the mould is lifted off and placed on the ground for pouring. The operations of throwing over the plate and flask, and of returning the mould to its upper position in the machine, are rendered easy by counterbalancing, double-acting springs. For the cope or upper half of the pattern, one of the square or round stand machines is used.

As indicating the saving in the cost of castings when moulding-machines are used, those fitted up for moulding brake-shoes are a good example. Two men on a job of this kind in a fast shop will put up and pour two hundred and fifty flasks or five hundred shoes for a day's work. When it is considered that each shoe weighs twenty-four pounds, it will be seen that a large tonnage is thus produced. On a thirty-six-inch round, double-shaft machine, fitted with a mower-wheel pattern, ordinary moulders make the moulds for six cents each. On the floor this job, done by skilled moulders, costs twenty-seven cents for each wheel. A fifty-two-inch square, heavy, double-shaft machine fitted up for moulding gears, with two men operating it, produces seven flasks in a day's run. When made on the floor, a moulder and helper will turn out only three moulds in a day, at the same time using ninety pounds more metal for each casting. On this job the saving in metal alone made the installation of the machine well worth while.

Another line of moulding-machines constructed on very much the same principle is the "Killing." This standard stripping-plate machine is built in all sizes, and is used as large as nine feet round and eleven feet square. It has the desirable long side bearings and is noteworthy on account of its simplicity. The Killing Straight-drop machine is said to be the simplest machine obtainable,

and well adapted for jobbing foundries. The cope and drag are in one machine, and the action is quick, with little or no adjustment. The Rollover Straight-draw machine is used for interchangeable work, all the operations being on one side, with the cope and drag in the same machine. It has an automatic bottom board adjuster and will handle thirty-six by twenty-four-inch flasks and give twelve-inch draw. The operation of these machines is in no way different from the description previously given.

For moulding light castings, especially of brass, the Adams method is probably as economical as any yet devised. While it gives most satisfactory results, its cost of instalment is not so great as would ordinarily be expected; and the pattern system is most simple, durable and economical. The operation is entirely by levers conveniently placed for rapid work, and in the main is similar to the perfected machines of the type already described.

The machines thus far mentioned are commonly known as hand ramming-machines, and while their object is to assist in the drawing of the pattern and to prevent the waste of time in patching, they in no way relieve the manual labor of ramming and handling the sand. During the time of perfecting the hand rammers there was another line of development being worked out to reduce this labor, which was effected by machines called power rammers.

The first moulding-machines of this kind used extensively in this country were the hand squeezers, through which power was transmitted by levers or toggles to press the sand to the required hardness. They materially assisted the moulder in ramming, and were generally employed in connection with the sand-match or match-plate, but very seldom proved as economical as was originally hoped for them, as it was found necessary to hand-tuck all depressions. The sand, when squeezed at low ve-

locity, acts more or less as a solid, and will not flow into deep crevices when the pressure is applied.

This difficulty was very largely overcome by the modern moulding-machine of the Arcade Company. It effectually rams and draws the patterns, all the operations, including rapping, being done by hand. As many as forty moulds an hour can be turned out by one man handling his own sand and moulds. An average of two hundred and eighty moulds in seven hours was taken from foundry records covering a period of thirty days. No new principle is advanced by this machine, although the construction reflects the highest mechanical skill; and it works wonders on jobs of small castings.

The next step along the line of power rammers is shown in the plain power ramming-machine of the Mumford Company, by the use of pneumatic, hydraulic, or steam presses for ramming the sand. These machines are generally used with sand-matches or match-plates, and relieve the labor of applying the levers of the hand squeezers. But they are still subject to the difficulty of getting deep crevices of the patterns rammed without hand-tucking, although on flat work they are wonderfully efficient. They are provided, however, with vibrators which render them of great utility. A pad placed conveniently at the left front of the table when pressed by the workman operates a valve admitting air to the vibrator. The yoke has a clearance of thirty-six inches between the rods, allowing ample space for the working parts. For use with loose, gated, and plated patterns, a snap-flask and match-board with vibrator is the usual equipment.

With ramming thus effectually accomplished by power, usually supplied by compressed air, it was a forward step to adopt some of the features of the stripping-plate for drawing of the patterns. Along this line of development there is what is known as the Split Pattern Power Ramming-machine, of the Mumford make. In the operation

of these machines the work is power-rammed, and the patterns are power-drawn from the sand, the vibrator being employed for freeing the patterns from the sand and reducing the amount of stripping required. For such work as valves, cast-iron and malleable fittings, and small brass castings, which are made in large quantities, these machines probably produce the cheapest moulds. A new appliance of great utility for these machines is the hand starting pattern draft, which is used in combination with the power draft. A slow-acting cam, operated by a hand lever, starts the patterns more gently than any power draft can, but acts for the first quarter inch only. Further movement of the hand lever then opens a valve to the power draft, which acts quickly and for any depth.

A development on somewhat diverging lines — the plain jolt ramming-machines, in combination with pattern-drawing and pressure ramming devices — has been going on for years, but its possibilities have not yet been fully realized. The Herman Jarring Moulding-machine comes under this general head, as it effectually jars up deep and heavy moulds, including such large flasks as sixty by sixty, to any height, and the ramming is even all over. Hand ramming is entirely eliminated, the mould is rolled over, and the pattern drawn. In operation, all that is necessary is to place a flask on the machine, fill with sand and turn on the air, and by an up and down movement of the table-plate striking upon a resilient surface, the mould is completely rammed in from thirty to forty seconds. No venting is required, and no scabbing, cutting, or swelling of castings is possible. A further advantage of these machines is that they allow of the use of the patterns and flasks in use in the foundry, as they are.

A general line for almost all kinds of foundry work is found in the Tabor Moulding-machines. It comprises the rockover type in which the mould-board and pattern are raised in a positive vertical direction by the handle in

front of the machine, and the light power squeezer for bench work. There is also a power squeezer, split-pattern machine for heavier work. They are operated by either pneumatic, hydraulic, or steam rams. The operation of these machines is in no way different from that of others of the same general type.

The J. W. Paxson Company has evolved a moulding-machine embracing the Glenwood rockover machines and a power ramming-device, by which the operation of ramming the sand, hitherto necessarily done by hand on all rockover machines, is automatically accomplished by power. It is simply a combination of the ramming device and any of the standard rockover moulding-machines. Grate-bars, gear-wheels, stove-plate castings are especially adapted to this machine, because the pattern can be returned.

The Berkshire Automatic Moulding-machine is a decided departure from the construction designs of any of the machines thus far described. The record of one week's run shows a total of five thousand, six hundred and two complete moulds made in fifty-six hours, or an average of nine hundred and thirty-three and one-third moulds per day. The machine brings up its own sand, riddles it on the patterns, tucks and rams it, and draws the patterns entirely by power controlled by levers. Sixty moulds an hour from this machine is guaranteed, but in actual practice these figures are exceeded by about twenty-four per cent.

The evolution of moulding-machines presents many interesting phases of the art, and one can not help wondering at the lapses of time (generally a number of years) between the stages of improvement. This has probably been due to the wide range of requirements in moulding to meet the demands as to size and variety in castings. The requirement of simplicity has been followed in the design of all practical machines, and some have been devised for special purposes, and could not be

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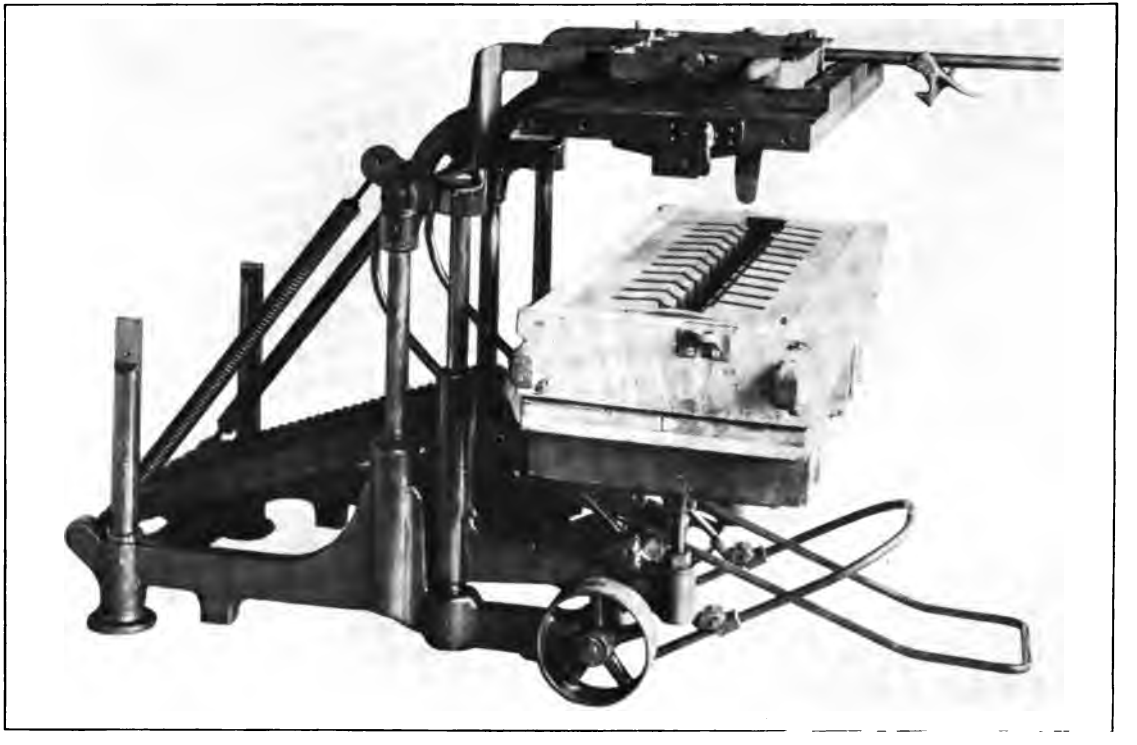

ROCK-OVER DROP MOULDING MACHINE

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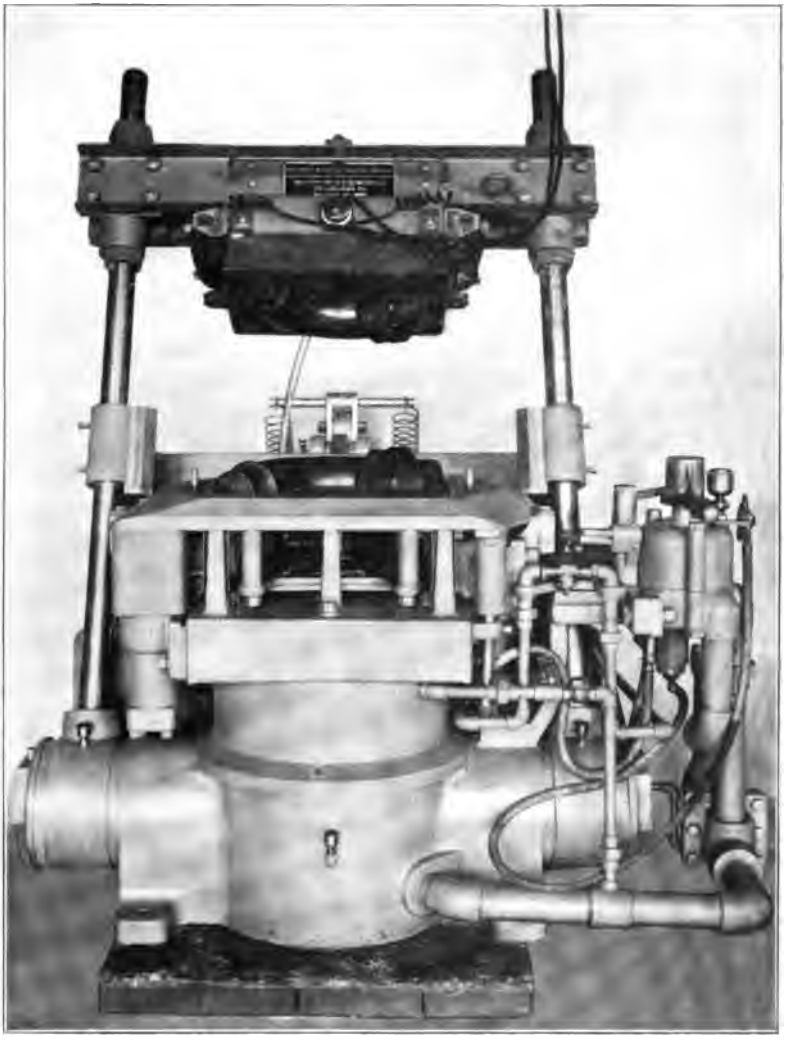


MOULDING MACHINE WITH PATTERNS IN PLACE READY FOR WORK

used economically for any other. Even in the latest great advance in moulding, the machine, which will do much more than any ever perfected, is not adapted to all uses. It is hardly suited for very large work. The limit of utility, it is thought, is reached with a flask about thirty-six by forty-eight inches. The machine is made by the Mumford Company, under patents granted John A. Rathbone, for certain improvements and additions to the previous models made by this concern.

To what extent cold steel in conjunction with compressed air has taken the place of manual labor, is clearly shown in the operation of this new moulding-machine, which is considered by experts an important addition to foundry appliances. By the use of this invention, multiple-moulding, the dream of foundrymen from time immemorial, is an accomplished fact; and its advent is the beginning of a new era in foundry practice. The machine will do things with marvellous exactness, which hitherto have been regarded as impossible by practical men. The old methods of slow laborious operations of human machines (as the moulders were) are giving place to the hard cold machines of steel operated by compressed air and electricity. The success of multiple-moulding for the first time realized, forms a new chapter in the archives of the mechanical world.

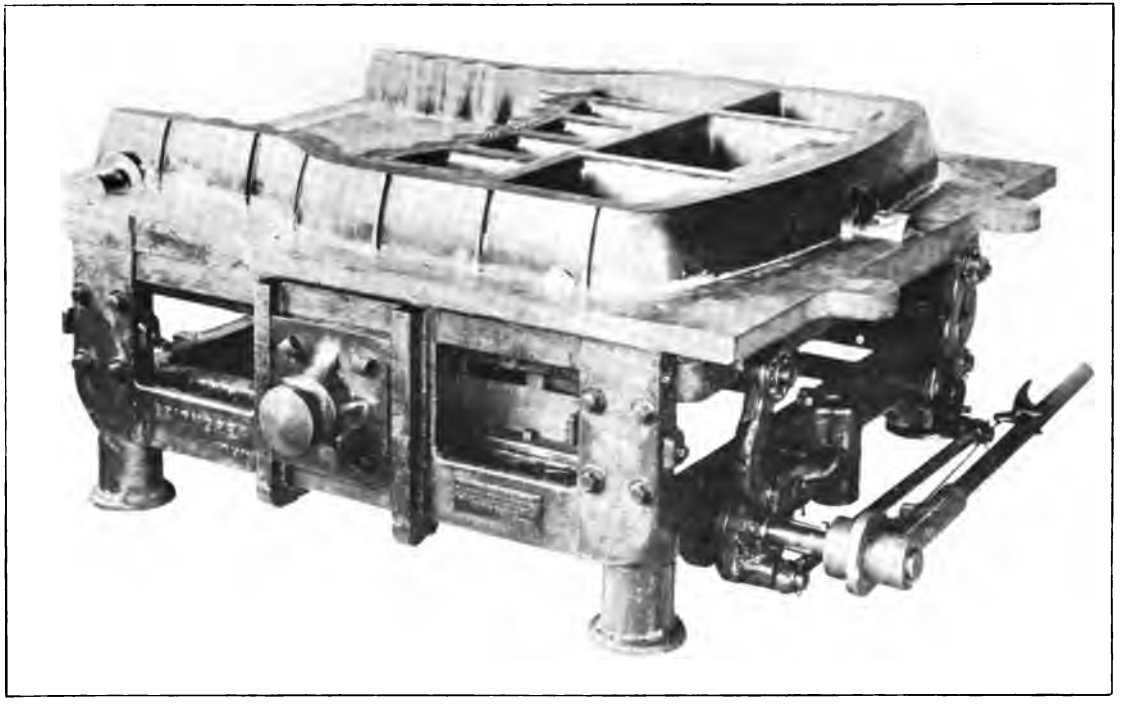
Multiple-moulding, in the words of the inventor, "is that branch of the moulding art where the upper face of the cope of one mould is formed to make the drag face of a superimposed mould." It is the broadened use of moulds, by stacking them one above another as high as the pouring can be conveniently done, that is working such a revolution in foundry practice.

The Chinese in their experiments carried out the idea of the multiple stack, but they were confined to flat-back work, as they never found any method by which they could get an irregular drag impression. In the Patent Office records of this country and of Europe, there are

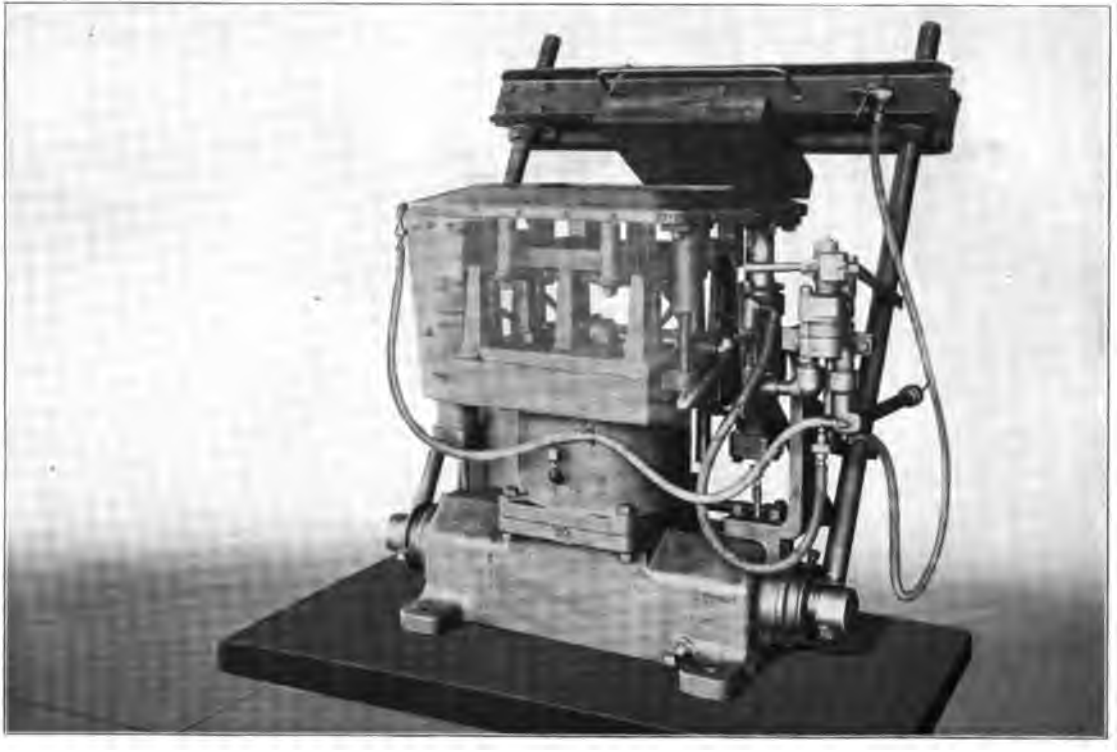
many schemes for multiple-moulding, all of which failed because it is impossible to press an irregular shaped pattern down into a struck surface of sand and get a perfect impression of the pattern.

By the discovery of a new principle, which is the main feature of the Rathbone machine, the production of a perfect drag mould is for the first time accomplished. It is done by projecting the sand against a down-faced pattern with sufficient velocity to cause the loose sand to be thrown into every detail of the pattern, the same way that the riddled sand falls into the detail of an up-faced pattern by gravity. All the advantageous features of other machines in general use have been incorporated in this new machine, and it can do everything that can be done by any individual machine, and in addition it makes a complete mould, while the other machines are making a half mould.

The power cylinder is carried in the bed plate of the machine, and is sixteen inches in diameter, exerting, under compressed air at eighty to one hundred pounds, a pressure of ten tons. Above the cylinder and secured to the ram is the pattern-drawing device, within which is the pattern plate. Incorporated in the cylinder is a practical jolt rammer which is used in conjunction with the power rammer, with the result that every crevice of the most intricate pattern is completely tucked and rammed. Above the body of the machine and secured to the yoke swing, the rods of which have a clearance of three feet, is the upper head block. To this plate are attached the drag pattern and the vibrator for tucking the pattern, and also the electro magnets for engaging the sand frame as the mould is rammed. To the right of the operator and easily within reach, are the air valves for operating the ram, the swing-head mechanism, and a compressed air hose with valve and end to throw an air jet on the cope patterns, to clean them of loose sand after each mould. On the head is an electric switch to operate the electro



MOULDING MACHINE FITTED WITH BOILER SECTION PATTERN



SPLIT PATTERN, POWER RAMMING, WITH HAND-STARTING PATTERN DRAFT

magnets. The whole machine may be mounted on flanged wheels to run on a narrow track about the foundry.

When the machine is ready for the mould the cope pattern is up-faced on the bed plate, while the drag pattern is in a reverse position attached to the head plate, but in perfect alignment with the other. The operator lifts a flask and places it over the lower or cope pattern so that the holes in the lugs engage the pins in the drawing-plate. He then riddles the facing-sand over the pattern until it is entirely covered. The jolt rammer is then set in motion, the operation simply raising the entire frame about three or four inches and dropping it on the solid base, and so quickly is it done that the half-dozen or so jolts require scarcely as many seconds. The narrow sand-frame is then placed over the flask with the pins engaged and sand shovelled in, filling it, when it is levelled off flush with the edge.

By turning the smaller valve to the right the swing mechanism pushes the head forward, bringing the drag pattern in perfect alignment with the cope, and is made secure by a toggle-joint arrangement behind. The machine is then ready for the ramming, which is controlled by the large air valve. When the valve is opened the mould-frame under the tremendous pressure exerted by the ramming-head, makes a mighty thrust upward, thus effectually ramming both the cope and drag moulds. The vibrator is automatically set in motion at the same time to jolt the drag pattern, and the electro magnets hold the sand-frame to the head block.

Reversing the air valve, the mould flask is carefully drawn away from the drag pattern; and the swing head slowly falls back into place, by the reverse action of its valve. The drawing of the cope pattern is done in precisely the same way. The entire frame supporting the flask containing both impressions of the complete mould is raised from the bed containing the pattern, by simply opening a small valve which puts in action pneumatic

rams as shown on the sides of the frame. No matter how deep the pattern may be, the machine carefully draws away the mould from it. The flask is then lifted off and stacked on the multiple pile. The whole operation requires less than a minute, and a complete mould has been made in one flask, and with half the amount of sand used in any other process.

A continuous sprue cut is made through each stack by cutting in each mould, as it is made, a sprue hole in the cope of the top mould through the drag of that mould into the pouring-basin of the mould below. At first thought it would seem that the castings in the bottom moulds would not be so good as those on top. Naturally they would be heavier than those nearer the top. But this is not the case, and the expected does not happen. The bottom mould does not burst, or run out, or strain; nor does the bottom of the long sprue cut. This is because the liquid metal does not fall in a stream to the bottom of the hole, but, "wetting" the sides, reaches the bottom mould fully as gently as if it had fallen only one-tenth the distance from the open lip of a hand ladle.

That the bottom does not strain is due to the fact that, by the time the metal has filled the next mould above and has risen to the level of the mould above that and filled it, when the head has become sufficient to do some straining, either the gate or the casting below has set enough to prevent the easy access of any more metal; and, as the pressure of the head increases, so does the resistance to its entrance. Another reason for less straining than is expected in these bottom moulds lies in the fact that never before were moulds so perfectly weighted and held as those at the bottom of a stack of moulds in iron flasks. Except for the top mould, no weight is needed as the lower mould joints are made good by the weight of the upper moulds upon them. The pressure of the metal on a mould at the bottom of a stack forty-five inches high is only about twelve pounds per square inch, while the sand in

those moulds has been rammed forty pounds per inch, and is so held that it can not give way.

The time required to make a complete mould by the Rathbone machine is a little less than a minute, about half of that time being used by the operator in lifting the flasks off and on and cleaning the patterns for the next mould. Seventy-five moulds, fourteen by sixteen inches, have been made by one man, shovelling his own sand and lifting on and off the flasks, in an hour. The speed for cored work, with one man operating the machine, shovelling, and stacking, is over forty moulds an hour. On steel castings with one man operating the machine, riddling his facing-sand by hand, and shovelling his backing-sand from the heap, stacking his moulds and setting the core, the speed is over thirty moulds, of the same size mentioned, per hour. As compared with the work of the hand moulder, it is as twenty-five to one, effecting a saving of forty to seventy per cent in labor, and eighty-eight per cent in foundry floor space.

The skill required of the operator is reduced to the rapid handling of the valve lever. The operator has no drawing of patterns, no patching of moulds, and no slicking to do. As each section of the flask has both the cope and drag impression, and as ramming for both is done in a fraction of a second, it will be seen that the slow and laborious work of ramming moulds is entirely eliminated. The installation of the machine in a certain steel works produced an unlooked-for effect in the work of the moulders. Before the machine was in operation their average daily output on a certain job had been gradually reduced to twenty per day, but when the machine was running, the output quickly increased to thirty per day for the same job. The cause of the increase is plainly evident. Although the machine is generally operated by compressed air, whatever power is most conveniently at hand in the foundry — such as hydraulic or steam — can be used equally well. If direct

current electricity is not available for the electro magnets a mechanical device is substituted to operate the sand-frame.

Any one familiar with foundry methods is accustomed to seeing moulders throw handfuls of compact sand against the pattern face, in order to tuck the crevices and intricate portions of it. This practice of utilizing the force of gravity in the simple and effective way, insures more perfect moulds with less patching of hand-work. Experience covering a period of many years has demonstrated that the principle involved in making moulds by the force of gravity, is a correct one when properly applied. In fact, the proper use of this method has entirely solved the problem of moulding by machinery, in overcoming the difficulties which have been met with in trying to squeeze, jar, or compress the sand uniformly around the patterns.

During early experience with the gravity method, it was seen that merely dropping or even trying to force the sand into the flask from an elevation would not pack it. In fact it was found that, by reason of the increased tendency to spray or disintegrate, the farther the sand was allowed to fall the less it would pack. The inventor of the Mitchell-Parks gravity method discovered, however, that by first packing or compressing the sand into bodies of the proper size and shape such bodies could be uniformly packed into the flask to any degree of firmness desired. This was effected by dropping the sand only a comparatively short distance, ten feet being ample for any class of work.

While this important discovery formed the basis of this gravity method of moulding, further experiments demonstrated that to practise such a method successfully it was necessary:

"To compress or pack the sand into bodies or strips as long or longer than the width of the flask, but of such thickness that a series of such bodies are required to fill the flask.

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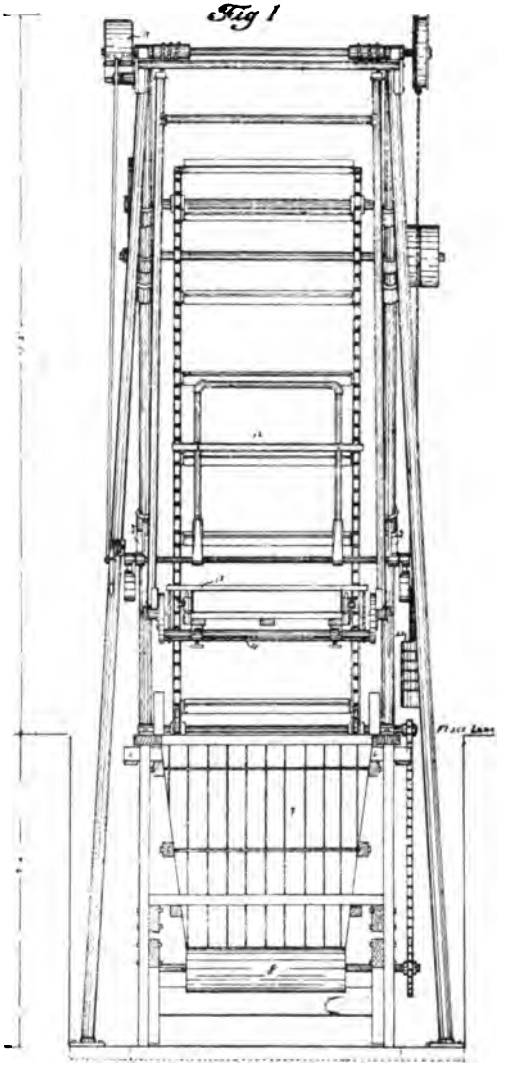

FRONT ELEVATION

Showing iron framework for supporting upper part of machine, and sand hopper in excavation below floor line

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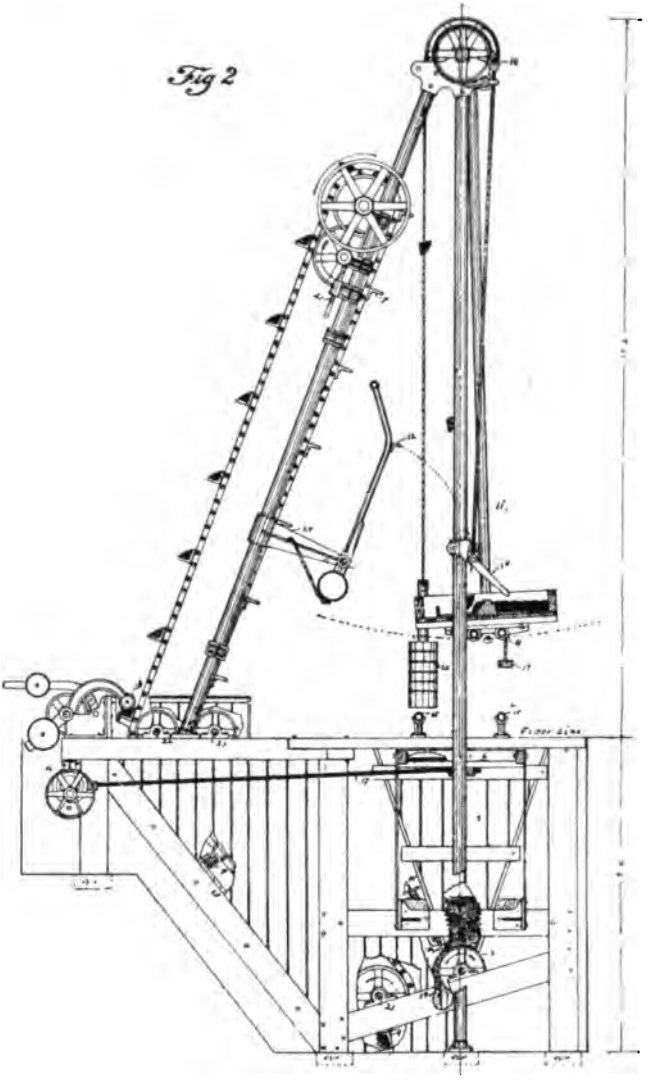

SIDE ELEVATION

Showing sand hopper in excavation below floor line, means for feeding sand to the elevator, and the discharge of the compressed bodies of sand into the flask while the latter is swinging back and forth.

"To provide controllable means for automatically compressing the bodies or strips of sand to the degree of firmness necessary to suit the class of work.

"To provide a practical mechanism for elevating and for discharging the bodies of sand from a sufficient height to cause same to pack uniformly together around the patterns in the flask.

"To provide suitable means for moving the flask back and forth across the line of fall of the bodies of sand to cause same to be discharged into the flask in their proper relation to each other, so as to ram up the mould uniformly throughout."

It was necessary to design and perfect a machine that would not only meet these requirements and accomplish the results desired, but at the same time, if possible, avoid all complications and provide a machine that was simple, practical, and durable, and that any one with ordinary intelligence could operate. How well the makers have succeeded in this undertaking competent judges can determine from the description and operation of the machine.

The first automatic moulding-machine was set up and operated in a foundry at Belleville, Illinois, during the latter part of 1905. It was in some respects a crude machine, but it demonstrated that the principle of moulding by gravity was a correct one. Further experiments, and the construction of improved machines, eventually led to the perfection of the now reliable Gravity Moulding-machine. It will be well to bear in mind that the Gravity Moulder occupies a unique place in moulding art, and should not be classed or confused with other moulding devices, because many are merely more or less convenient tables for the moulders to do the work on. The gravity moulder is neither a mere ramming-machine nor a mere pattern-drawing device, although it performs both these important functions in a perfect manner. Under the control of a single operator it performs all the necessary work to complete a perfect mould in the shortest possible time.

In the first place it automatically riddles the sand and compresses it into properly shaped bodies to any degree of firmness desired; and the flasks are automatically filled with a series of these compressed unitary bodies of sand. The same operation that automatically fills the flask simultaneously rams up the mould uniformly throughout, regardless of the depth of the flask or the size and shape of the patterns. It strikes off the surplus sand from the top of the filled flask, and the matchboard with pattern is automatically rapped with the pneumatic vibrator while the pattern is being drawn. It furthermore draws the pattern perfectly straight from the mould without the aid of stripping-plates and without breaking down the sand on the most intricate or difficult work. It accomplishes all these operations in a few seconds' time, making a perfect mould so quickly in such a simple manner, as to cause those who have seen the machine in operation to wonder that it was not thought of and introduced fifty years ago.

In operating the gravity moulder, the sand is usually tempered at night and brought up by the night watchman or helpers, with cranes or other suitable means, and placed in two large heaps, one on each side of the machine. Three men constitute the full crew for operating one machine, but, in fact, only one man really operates it and makes the moulds, the others being employed to keep the hopper supplied with sand, to bring up the empty flasks, and to take away the finished moulds. One helper keeps the machine supplied with sand, by shovelling it from one side into the automatic riddle, through which it falls into the hopper beneath. This hopper is kept partially filled so that the machine is supplied at all times, while the helpers are otherwise engaged in operating the cranes for bringing up the empty flasks and taking away the moulds.

On starting the machine by means of a lever which shifts the drive belt, a roller feeder at the bottom of the

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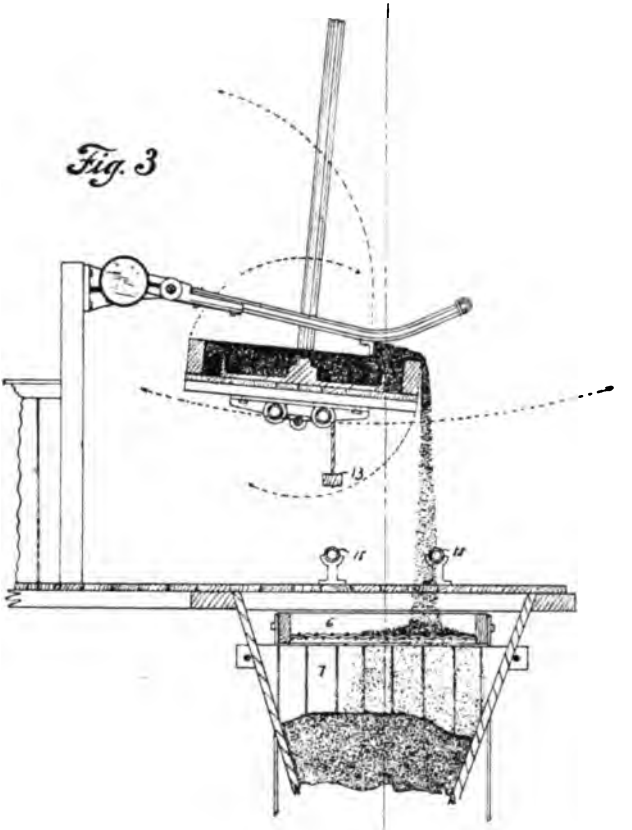
Fig. 3



CROSS SECTION

Showing strike-off swinging into position to strike off surplus sand from flask while the latter is still swinging, the surplus sand falling through riddle back into hopper. The dotted line indicates travel of strike-off into and out of position, the swing of cradle back and forth, and also indicates how the flask is turned after it is completed and clamped to the cradle.

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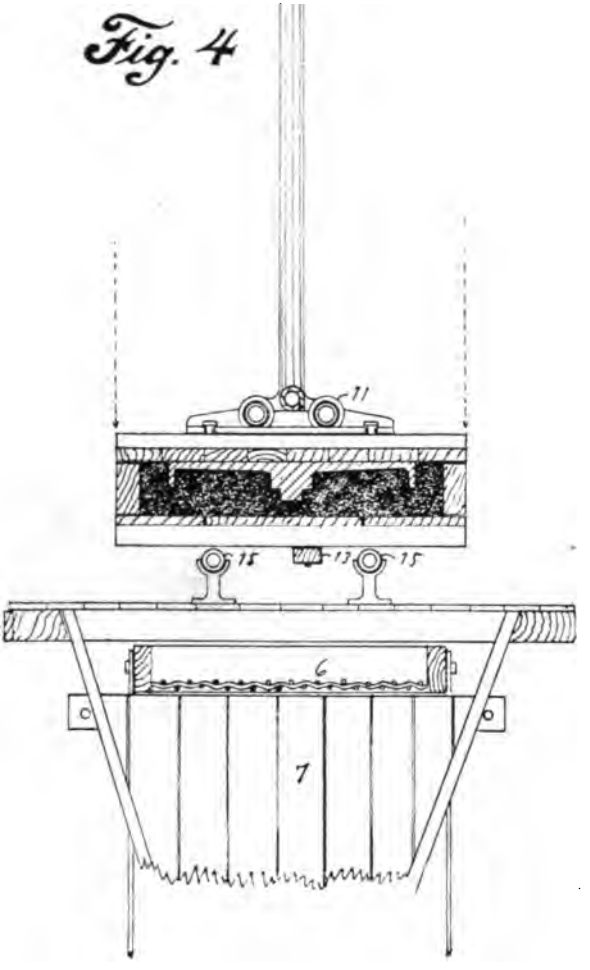
Fig. 4



CROSS SECTION

Showing drag with bottom board clamped to cradle and lowered to supporting bars
Copes are clamped in the same manner, but without the bottom boards

hopper supplies the sand in an even stream from the hopper to the elevator; it is carried by the buckets of the elevator and discharged at the top into the flask below, which is supported on a swinging cradle. While it is being elevated, each bucketful of sand is engaged by a compressor which automatically packs the sand in the buckets. The pressure exerted by this compressor can be instantly adjusted so as to pack the sand in the buckets to any degree of firmness desired, and by this means the moulds can be made hard, soft, or medium, as may be required.

It will be seen that instead of the loose sand being discharged by the elevator into the flask, it is deposited in the form of compressed strips or bodies extending the full width of the flask; and, as the flask, while being filled, is swung back and forth, the bodies or strips of sand wedge in beside each other, building up the mould layer by layer, packing it uniformly throughout. In other words the flasks are rammed up by a succession of compressed bodies or strips of sand falling beside each other, until a layer is formed across the entire area of the flask, after which additional layers are built up in the same manner until the whole mould is formed of one solid mass of sand of the same degree of firmness. As these bodies of sand are discharged with the greatest rapidity, only a few moments is required to ram up a large flask.

In making a mould, the operator simply clamps a matchboard with the lower half of the pattern in position on the cradle. A flask is then placed in position on the matchboard, and when the machine is started by means of a lever, the swing carrying the flask is swung back and forth until the flask is filled and rammed up in the manner just described. The machine is then stopped by the same lever, and the strike-off swings into position and, while the cradle is still swinging, strikes off the surplus from the top of the flask, whence it falls back

into the hopper below. The strike-off then swings back out of the way.

The flask is then quickly clamped to the cradle by means of a special clamp, turned over, and automatically lowered to the supporting bars beneath. The clamp is then released, and by means of a brake lever, the operator causes the cradle carrying the matchboard to rise back to its normal position, drawing the pattern perfectly straight from the mould. This mould or drag is then carried away by one of the jib cranes, or other suitable appliance and placed on the floor, while at the same time an empty flask is being placed on the cradle, and the operation repeated as before, the entire work of completing the mould requiring only a few moments.

It will of course be understood that, when the desired number of lower halves or drags of any certain mould have been completed, the matchboard is removed from the cradle, and another board with the pattern for the upper half or cope is then secured in position, and the same operation performed, as in making the drags, except that the special bail used on the tackle for carrying away the moulds is employed to carry the copes by the gudgeons on the ends of the flasks, to facilitate turning and placing them in position on the top of the drags or lower halves, thus completing the moulds without lifting or hand labor.

Bottom boards are clamped to the drags before they are turned in the cradle and are carried away from the machine with the flask for the purpose of supporting the sand. The copes are provided with special bars which support the sand perfectly and permit turning them in bails on the crane without danger that the sand may drop out. It is not necessary to tuck the bars by hand when ramming up the flask. In fact no work of any description is necessary in making a mould, other than controlling the movement of the cradle while swinging back and forth, working the levers, and so forth. The

entire operation is practically automatic, which is remarkable in view of the simplicity of the machine.

To operate the gravity moulder to its full capacity, it is necessary to provide suitable means to handle the flasks and moulds. The capacity of the machine is practically limited only to the facilities employed for bringing up the empty flasks and taking away the finished moulds. A very desirable system for this purpose consists of two properly constructed jib cranes with reach enough to cover sufficient floor space for handling the moulds for a day's run. If it is inconvenient to employ jib cranes, any suitable overhead carrying system will answer the purpose.

VIII

GRAPHITE

THE VALUE OF GRAPHITE IN THE MECHANIC ARTS

THE RARE QUALITIES OF GRAPHITE — ORIGIN OF ITS NAME — USED IN THE 14TH CENTURY — FIRST MANUFACTURE OF PENCILS IN ENGLAND — NATURE AND PROPERTIES OF GRAPHITE — THE CRYSTALLINE AND AMORPHOUS FORMS — IMPURITIES — ITS DIFFERENCE FROM OTHER FORMS OF CARBON — ORIGIN — PRODUCED IN THE LABORATORY — GRAPHITE VEINS — AMORPHOUS GRAPHITE THE MORE ABUNDANT — LOCATIONS OF THE PRINCIPAL DEPOSITS — THREE CLASSES OF DEPOSITS — AMOUNT PRODUCED IN THE UNITED STATES — PURIFICATION OF THE ORE — MANIFOLD USES OF GRAPHITE — MANUFACTURE OF CRUCIBLES — SMALL PROPORTION OF THE WORLD'S GRAPHITE USED IN PENCIL-MAKING — METHODS OF PREPARING THE PENCIL LEADS — GRAPHITE AS A LUBRICANT — AS A PIGMENT — OTHER USES — ARTIFICIAL GRAPHITE.

GRAPHITE, either in the natural state or as an output of the electric furnace, is a remarkable substance, and may truly be said to be one of the most important products of the mineral realm. Of all the non-metallic minerals with which the industrial world is more or less familiar, the iron-black and the steel-gray graphite yield probably the largest number of valuable and almost indispensable products for every day use. These cover an exceedingly wide and varied range of usefulness in the commercial arts. In composition and chemical and physical properties graphite affords to mineralogists an interesting field of investigation and experiment; and new uses for the mineral, generally in combination with other substances, are being discovered.

From the earliest use of graphite (otherwise called plumbago and blacklead) by the ancients in painting stone vessels, down through the Middle Ages, when the

farmers of Keswick, England, marked their cattle with the mineral, to the making of pencils, and the more recent use in the making of refractory vessels and foundry facings, its use as a lubricant, stove polish, and paint, finally to its use in the electrical industry for commutator brushes, it has displayed the quality of being absolutely inert and, when pure, unchanged by any known exposure. It is unaffected by water, brine, acids, alkali, smoke, steam, moisture, sulphur fumes, extreme temperature, or by any chemical or climatic condition. These rare qualities and the liberality with which Nature has distributed the mineral throughout the world — although in few very large deposits — render it of great economic value in the mechanical arts.

The name *graphite* is derived from the Greek γράφω, I write, and was given to the mineral by Abraham Gottlieb Werner (1750–1817) because of its softness and unctuousness, whereby it was largely used for marking and decorating smooth surfaces. The name "plumbago" seems to be derived from the Italian "grafio pliombino," which indicates its use; but the former name is preferred by commerce. The term "blacklead" as applied particularly to pencils is, however, an erroneous one and should be regarded, from the viewpoint of to-day, as unfortunate, since no lead in any form enters into the composition of the mineral. To call the pencils of daily use "graphite pencils" would seem to be preferable.

Graphite is one of the natural forms of carbon but, although the mineral has been known for such a long time, its true chemical nature was not determined until the latter part of the eighteenth century. The earlier chemists and mineralogists believed that the mineral contained lead, and, because of its property of leaving a black mark on paper, they naturally adopted the name "blacklead." In German this is signified in the term "Reiszblei," drawing-lead. It is so widely different

from other forms of carbon (charcoal and diamond) in form, color, hardness, and other physical properties, that Brodie considered it a separate element. This supposition was unfounded, since graphite, like the other forms of carbon, burns in a current of oxygen to carbonic acid gas.

The oldest authentic records of the mineral date back to the beginning of the fifteenth century, when Cennino Cennini,* born in Florence, Italy, about 1370, mentioned the use of a pencil for his paintings. It was composed of two parts of lead and one part of tin. During this period graphite was used in making crucibles in Hafnerzell, Bavaria, for the use of alchemists in the melting of precious metals in their vain search for the "stone of the wise." For centuries this remained a small industry; it was the application of graphite in the manufacture of pencils that, because of the purer qualities required, stimulated the search for an economical method of refining the mineral.

Graphite seems to have been first recognized as a distinct mineral by Conrad Gesner who, in 1565, in his work "De rerum fossilium figuris," mentioned the use of lead pencils, and as a curiosity added a picture of a blacklead pencil, with this notation: The pencil represented below is made for writing, of a certain kind of lead (which, I am told, is an artificial substance termed by some, English antimony) sharpened to a point and inserted in a wooden handle.

The actual manufacture of pencils was begun with the discovery of the celebrated mines of Borrowdale, in Cumberland, England, which occurred in 1564; but it is not definitely known where the first pencils were made. It is probable that the art-loving Italians were the first to use the mineral in drawing, as its superiority over other marking substances of the time was soon recognized.

*"Traktat der Malerei," Vienna, 1888.

The graphite for the Italian pencils was imported from England through Flemish merchants, who gave it the name "Flanders Stone," although no graphite was then mined in Flanders.

It was not until nearly two centuries later that the German chemist Heinrich Pott (1692–1777) proved that graphite contains no lead, although it is possible that he demonstrated with molybdenite rather than with real graphite, as the chemists of the time did not distinguish between the two minerals.

A few years later Karl Wilhelm Scheel (1742–1786) established — in 1779 — the true chemical nature of these minerals, which are so similar in appearance, and proved by the oxygen test that graphite is an elementary substance, a kind of mineral carbon. Noted chemists of the time, however, doubted the existence of carbon in graphite, because the analytical methods were very imperfect; and it was not until 1800 that Mackenzie, having demonstrated the fact beyond question, added graphite to the carbon group.

Graphite is frequently found in embedded foliated masses, also in columnar, radiated, or slaty forms, and in dense earthy deposits having a dull coal-like lustre. Its characteristic properties are its softness, greasy feeling, and adhesive quality of soiling everything with which it comes in contact. Pure graphite is insoluble as well as infusible, and is highly refractory although combustible; it is an excellent conductor of electricity. It possesses peculiar lubricating qualities and has a softness and smoothness shared in equal degree by no other solid substance. It imparts a brilliant polish to all surfaces coated with it, and resists all chemical action and climatic conditions.

Nature yields graphite in two forms, the foliated or crystalline variety, which is in flakes; and the amorphous, or non-structural. While both are chemically the same, physically they are very different in nature, texture,

action, and effect. Graphite of the flake variety even when thoroughly pulverized still remains in the form of minute fish-scale-like flakes, which are visible to the naked eye; amorphous graphite, on the other hand, having no structural form, is susceptible of pulverization to a particular degree, and may be ground to a powder of impalpable fineness.

The relative values of crystalline and amorphous graphite as given by high, unprejudiced authority, show that

"the crystalline variety can be used for all purposes for which graphite is required, but its chief uses are in the manufacture of refractory products, lubricants, electrotypers' powder, and pencils, for which it is especially adapted on account of its purity. The refining of crystalline graphite is accomplished with but little difficulty, and the resultant product is usually very pure and free from any injurious compound.

"The occurrences of amorphous graphite are very much more abundant than those of the crystalline variety, but, on account of the difficulty experienced in refining the crude ore, many of these deposits are not, at the present time, of commercial value. Schists are often impregnated with graphite to such an extent that they become graphitic schists. Usually these schists contain also minute particles of quartz, and, although they may carry a very high percentage of graphite, it is impossible in many cases, to obtain from them a commercially pure and marketable graphite. This is due, partly, to the intricate manner in which the grains of quartz and graphite are intermingled, which makes it almost impossible to separate the quartz completely from the graphite, even by extremely fine crushing. In the making of lubricants, pencils, crucibles, and electrical supplies, pure graphite is essential." *

In the ore the impurities contained in or associated with graphite are of two kinds. There is the matter of the rock or clay which contains it, and, secondly, the earthy matter intimately blended with it. From the former it may often be easily separated by the ordinary

* "Production of Graphite," U. S. Geol. Sur., 1903, 1121.

process of crushing and washing, and is frequently obtained in a state of nearly pure carbon. The other impurities of an inherent nature, like the ash in coal, consist chiefly of silica, lime, iron, clay, and volatile substances, and are apparently mixed rather than chemically combined. The graphite of commerce when freed of impurities is of a grayish-black color with a somewhat metallic lustre, and is perfectly opaque. As carbon is always in some degree associated with iron, the older mineralogists described the mineral as a "carburet of iron"; but after years had passed, bringing a fuller knowledge of the peculiarities of the substance, it was demonstrated that the iron is present in the mineral, but not as a carburet.

The value and uses of graphite are largely determined by the character and quantity of the residual substance contained in it.

"Sometimes it exists as a mere trace, or it may amount to more than 50 per cent of the mass. The market value is, however, not directly proportioned to the earthy matter or ash it contains, as even when this is in large amount, if very fine and equally diffused, it may not forbid the employment of the material for the manufacture of cheaper grades of pencils, and other uses for which a kind is demanded that commands a high price. For the manufacture of crucibles, graphite may contain much ash, provided the quantity of lime, magnesia, and so forth, is small. Much of the alkaline earths renders the substance fusible." *

"Hydrogen † enters very often into the composition of graphite ores, and in the table on p. 234 the investigations of several well-known chemists in that direction, are laid down.

"The amount and nature of the impurities generally met with in graphite ores vary as much as the contents of carbon. In the majority of cases the percentage of carbon in a graphite is all that is asked, but in comparing various ores for specific purposes, it is not less important to know exactly the nature of the accompanying gangue and the percentages of the same. The pur-

* Universal Cyclopædia.

† Cirkel, "Monograph on Graphite," 96.

Locality	Carbon	Hydrogen	Ash	Authority
Ticonderoga	99.87	0.11	0.02	Luzi
Crystals of same	99.86	0.12	0.02	"
Ceylon	99.82	0.17	0.01	"
Siberia	99.89	0.10	0.01	"
Canada	86.8	0.50	12.6	Regnault
Canada	76.35	0.70	23.4	"
Canada	99.5		0.68	"
Borrowdale, Eng.	88.37	1.23	9.8	"
Artificial	96.97	0.76	0.04	

est natural graphite has invariably been extracted from veins, and, if properly hand-sorted, need not be subjected generally to mechanical refining; carbon as high as 99.815 per cent has been found in some of the natural vein graphite of Buckingham, Canada.

"The disseminated or flake variety, however, that is, the one which so far has furnished the bulk of the ore for the production of graphite, is composed for the greatest part of gangue, the graphite itself constituting but a small part of the ore. As a rule the percentage of graphite in disseminated ores which experience has shown to be economically useful should not fall below 5 per cent; but in New York State there is a mine which, owing to an elaborate system of refining, can treat ore containing as low as 3 per cent flake graphite, with a profit. The percentage of graphite generally met with in disseminated ores, may be put down as from 7 to 30 per cent.

"The case is entirely different with amorphous graphite ores; while perhaps 5 per cent flake ore might under certain conditions pay to work, owing to comparative ease of extraction of the graphite flakes, it is problematic whether an amorphous ore containing 30 per cent of graphite would pay to work, on account of the most difficult problem of concentration, and attendant loss in the tailings. As to the composition of the ore obtained from veins, the graphite in many cases entirely fills the latter. The amorphous graphite ores frequently consist of graphitic shales, slates, or anthracite-like material."

As graphite is widely different from any other form of carbon in its physical properties, so does it occupy a position distinct from the other forms in its chemical relations. One of the most striking illustrations of this fact is the effect of treatment with fuming nitric acid and potassium chlorate. In this test diamond is unaltered, while amorphus carbon is readily dissolved to a brown liquid, but graphite is converted through a gradual change into a yellow, transparent, scaly substance, a compound known as graphitic acid or graphitic oxide. This represents an oxidation product of graphite; it is always crystalline, and is obtained only from graphite, and not from amorphous carbon; hence it is the safest means of identifying graphite known at the present time.

The simplest chemical formula for graphitic acid is C_{24} H_9 O_{18}, according to Luzi, while Berthelot gives it as C_{28} H_{10} O_{15}. It retains in all cases, where the crystalline variety is used, the form of the original graphite as small scaly particles of the mineral, of a yellow color, and somewhat transparent. If an earthy amorphous graphite is used in the same test, the graphitic acid produced does not show any crystal scales, but represents a yellow amorphous powder of extremely fine division. As neither charcoal nor diamond yields similar compounds, Sir Benjamin Brodie was led to believe that graphite might be considered a particular and peculiar radical, to which he gave the name "graphon."

"When finely powdered graphite is heated with a mixture of one part of nitric acid and 4 parts of strong sulphuric acid; or when a mixture of 14 parts of graphite and one part of potassium chlorate is warmed with 78 parts of strong sulphuric acid, the graphite assumes a purple tint, but on subsequent washing it returns to its original color. It is, however, no longer graphite, but contains in addition oxygen, hydrogen, and sulphuric acid. When this compound is heated to redness it swells up with a copious evolution of gas and then falls to an extremely finely divided powder of pure graphite, which has a specific gravity of 2.25.

This process is employed for the purpose of purifying natural graphite.

"If certain graphites are heated with nitric acid they swell up considerably and produce round, longitudinal, wormlike forms having a circumference of from ¼ to ½ inch and a length of several inches. These forms are steel-gray, of metallic lustre, are bent and twisted in regular curves, and appear otherwise very characteristic on account of this regular structure. They consist of a number of oblong cells, densely grouped together, exhibiting on the outer surface long parallel folds and wrinkles. These forms are (and this is very important) very light in weight, and when put in water or alcohol always rise to the surface, even when saturated thoroughly with liquid. They are as a rule very plastic, can be put into any form, and can easily be compressed between the fingers. Their interior exhibits planes of a highly metallic lustre which, according to Donath, are supposed to represent a lamellar crystallization." *

This process, carried out on a larger scale, has been used for the production of graphite of exceptional purity, and of a very fine and equal division. Luzi and O. Ludecke † use this nitric acid reaction for the differentiation or classification of graphites. They hold that the graphites occur as varied modifications of carbon, and divide them accordingly into two classes, those which yield to the above reaction, and those which are indifferent to it. The former kind Luzi designates as "graphite," the latter as "graphitite." To the first group belongs the mineral from Ceylon; Ticonderoga and Amity, in the State of New York; Buckingham, Canada; and several foreign mines. In the other group, remaining indifferent to the nitric acid reaction, may be mentioned the Bavarian, Siberian, Bohemian, Moravian mines; those in Colfax County, New Mexico; South Australia; and all artificial graphites made by the electrical process.

* Cirkel, "Monograph on Graphite," 12.

† "Thonindustrie Zeitung," 1895, No. 8.

In all the mineral kingdom it would be difficult to find a substance about which so many theories have been advanced, so many errors made, and in which conjecture alone is arrived at, as in the study of the origin of graphite. For a very long time it was believed to be of purely organic character, under the supposition that it was the ultimate product of the destructive distillation of vegetable and animal tissue. This view is entirely plausible since pure graphite is carbon alone, and carbon is one of the constituents of animal and vegetable life. In many instances graphite is found to be the direct product of metamorphism on coal, as at Craigman, Ayrshire, Scotland. There it is altered to trap; but at Newport, R. I., the coal, highly metamorphosed in mass, varies from anthracite to graphite, and is classed by some authorities as graphitic anthracite. There is still more direct evidence of the conversion of vegetable tissue into graphite in the coating of graphite which sometimes covers the impressions of fossil plants in metamorphosed, carboniferous strata.

Such indisputable evidence, however, applies only to graphite of the earthy, amorphous variety occurring in beds situated in crystalline limestone, gneiss, granite, slate, and other rock. In these beds amorphous carbon was converted into graphite, or disseminated in specks, detached grains, crystals, lumps, or masses, sometimes of remarkable purity. The detached particles or masses of graphite so occurring probably represent the carbon of the soft parts of animals, of which the bones and shells have supplied the calcareous matter.

In the theory of the formation of graphite from carbonaceous matter, the mineral constitutes the last stage in the process of conversion of vegetable matter, which has required thousands of years for its completion. In the beginning, the first stage in this long process, the woody and life-giving tissue was converted into peat which, after an extended period of time, became lignite.

The substance then passed through a range of bituminous coals to semi-anthracite and next to true anthracite. From anthracite there was a change into another semi state, graphitic anthracite, from which there appeared a practically pure carbon, the non-metallic mineral called graphite.

Certain European authorities * have shown that amorphous, carbonaceous particles in clay-slates have been converted into graphite by the metamorphosing influence of intruded igneous rocks. A good example of such transition is the deposit at Newport, R. I.; and J. S. Newberry has described an occurrence of this nature in the coal fields of northern Mexico, in the State of Sonora:

"All the western portions of this coal-field seem to be much broken by trap dikes which have everywhere metamorphosed the coal and converted it into anthracite. At the locality examined the metamorphic action has been extreme, converting most of the coal into a brilliant but somewhat friable anthracite, containing 3 or 4 per cent, of volatile matter. At an outcrop of one of the beds, however, the coal was found converted into graphite, which has a laminated structure, but is unctuous to the touch and marks paper like a lead pencil. The metamorphism is much more complete than at Newport, furnishing the best example yet known to me of the conversion of a bed of coal into graphite." †

"As to so much of the graphite as occurs in beds there seems, then, little doubt as to the origin from plant remains, which may be imagined to have existed in the form of seaweeds or to have been derived from diffused bituminous matter. Such desposits are regarded as originating through the metamorphism of the vegetable matter included in the original sediments, the agencies of metamorphism being both igneous intrusions and the heat and pressure incidental to the folding of the beds." ‡

However convincing the evidence of the direct transformation of carbonaceous matter into graphite may be,

* Beck and Luzi, "Berichte der Deutsche Chem. Gess," ft. 1891, 24.
† *School of Mines Quarterly*, 8, 1887, 334.
‡ Merrill, "Non-Metallic Minerals," 8.

such a hypothesis is untenable for the stratified graphites. Some authorities have advanced the view that, since the presence of graphite in veins implies its separation from solution at a high temperature, and that in this form the carbon is possessed of singular chemical properties and affinities, the mineral was formed from sedimentary residue through the intervention of some chemical reagents. This theory appears to be reasonable by the actual production of graphite by the chemist's magic wand. Jacquelain in his experiments brought about the decomposition of sulphuret of carbon in contact with metallic copper, at eight hundred degrees Centigrade, and obtained, with sulphuret of copper, amorphous graphite. From this result he was prompted to suggest that the native graphites occurring in veins may have originated from the distillation of volatile hydrocarbons into the fissures, cracks, and seams of rocks; and that these hydrocarbons have, by a decomposition not unlike that which is brought about by contact with the walls of coal-gas retorts, given rise to a deposit of carbon in the form of graphite.

"That graphite can be formed without the aid of a vital force is shown by its presence in cast iron, where it crystallizes out on cooling, in the form of bright metallic scales. This was observed by Scheele as early as 1778. Cast iron is a compound of metallic iron and a small amount of carbon. In the molten condition, however, it can dissolve a large quantity of carbon, up to as much as 4 per cent of its weight. This excess crystallizes out as graphite when the metal cools. The coarsely crystalline gray pig-iron owes its peculiar properties as well as its appearance to the presence of graphite; and when this form of iron is dissolved in acid, scales of graphite remain as an insoluble residue. Graphite has also been found in meteoric masses, which so far have not exhibited any traces of either plant or animal life; as for instance, the meteorite which fell in 1861 at Cranbourne, near Melbourne; and this meteoric graphite is, according to Berthelot, identical in properties with iron graphite. We may

thus conclude that the meteoric mass in which it was found had not been exposed to a very high temperature.

"As to the occurrence of graphite in volcanic rocks, there appears to be no doubt that the graphite has been formed by alteration of carbon fragments, which were enclosed in the molten magma during its eruption. For this reason we seldom observe an even distribution of the mineral through the volcanic rock, and fragmentary occurrences as small nests and pockets are the rule; as for instance, in the diamond-bearing rocks at the Cape, in the so-called 'Blue-Ground.' In this connection it may be mentioned that meteorites exhibit much analogy in their composition with these diamond-bearing rocks, and very often contain a large percentage of graphite, especially so if the meteor is composed mostly of iron. In some of these iron meteorites small concretionary masses of graphite can be found, and it is very likely that the mineral has been formed through precipitation and subsequent crystallization out of the molten metal while cooling. It may be mentioned, that in a few cases diamond is a companion of graphite in meteorites, and that sometimes larger and smaller crystals of diamond have been entirely changed into graphite in meteoric iron.

"As to the occurrence of graphite in the Laurentian formation, it must be said that the general habitus and association of the same with graphite and diorites seem to speak decidedly against its organic origin, at least as far as the graphite in veins and apophyses is concerned; and in this respect they resemble very much the occurrences near Passau, Bavaria. Field observations and microscopic study of the deposit in Madrid, Franklin County, Maine, indicate that the source of the carbon crystallized into graphite was presumably in the original sediments from which the beds were formed. This graphite is believed to be the product of the conversion and concentration of carbonaceous particles of sedimentary origin through the agency of the heated vapors issuing from the intrusive rock magma, now consolidated as pegmatite." *

It was the belief of Weinschenk that the source of graphite veins must be looked for deep down in the

* Cirkel, "Monograph on Graphite," 90.

earth. He attributes the formation of graphite in these veins to the probable action of volcanic gases, very likely of carbon monoxide and its compounds of the cyanogen group, and of iron together with carbon-dioxide and water, all of which having passed upward along the lanes of fracture with the eruptive rocks, were deposited through chemical agencies in the form of graphitic carbon. The presence of graphite in the rock mass in the vicinity of the veins is supposed to be due to planes and fractures of the rock in contact with the vein, and such graphite is sometimes of even higher value than that of the vein itself.

The disseminated form of graphite through limestone is without doubt derived from carbon originally present in the rock, probably of organic origin. The process of metamorphism may have been the same as that in which the limestone was converted into marble. The graphite occurring in veins, however, has certainly nothing in common genetically with disseminated graphite. For the source of its carbon, search must be made of the elementary and active forces deep down in the earth.

Although deposits of graphite are widely scattered throughout the world, many of them contain the mineral so thoroughly admixed with various impurities, and others are so far from modern transportation facilities, as to leave only a few of economic value to commerce. In some instances deposits of graphite in sufficient quantity have been found so intimately mixed with quartz and mica, as to render its separation too costly a process to compete with the product from other beds of more favorable quality. In the case of mica no process has as yet been discovered to effect the separation at a moderate cost.

Of the two classes of graphite, the crystalline and the amorphous, the former, commonly called " flake " by the trade, is of limited occurrence compared with the

amorphous variety. Because of this, and the fact that flake graphite is generally of a higher degree of purity, it is used mostly for the finer purposes of manufacture. Amorphous graphite, while occurring much more abundantly in nature, is of less value; but it finds, nevertheless, a ready use in a wide range of products to which it is well adapted. Until a cheap process for the extraction of the mineral is found, a great many deposits of the amorphous variety will remain of no commercial value.

Graphite has sometimes been discovered in mineral veins or rocks associated with precious metals, as in the Sunnyside extension mine, San Juan, where free gold occurs with graphite in quartz.* In the Silver Islet mine, north shore of Lake Superior, silver was invariably found with graphite, but the latter sometimes occurred in small pockets with no trace of silver.† It is also, occasionally, closely identified with magnetic and hematitic iron ore, in Scandinavia and in Canada.

From an economic point of view the world's supply of graphite is obtained from the actively worked and profitable mines in Ceylon, Austria, Bavaria, Siberia, England, and America. Workable deposits of more or less importance in Italy, Western Australia, New South Wales, and New Zealand, also contribute to the visible supply. The great deposits of Ceylon, which occur in granite rocks, have been worked since 1827, and seem to be inexhaustible, the mines now in active operation numbering more than three hundred. In the famous Alibert mine in Siberia, the deposits occur between syenite and granite, while those in Bavaria and Bohemia are confined to the gneiss formation. In America the more important deposits occur in several of the United States, in Canada, and in the northern part of Mexico.

For a comprehensive view of the formations, all

* "Mines and Minerals," 1901–02, 515.

† "Geology of Canada," 1887–1908, II, 28, H.

graphite deposits may be classed genetically into three groups, namely, veinlike occurrences, bedlike occurrences, and disseminations through the country rock.

"In the first mode of occurrence, that of veins, the graphite constitutes the filling of veins and cracks in gneiss, crystalline limestone, pegmatite, and granular eruptive rocks. Both hanging and footwall are easily discernible, and the direction of the vein is independent of the strike of the rocks traversed. Sometimes branches and narrow apophyses run out from the large graphite veins between the layers of country rock; they dwindle away and along their line of continuation isolated plates, patches, and pockets of graphite are deposited.

"The principal feature of the bedded masses is that their general outline and main direction conforms with the stratification of the country rock; they form in the majority of cases disconnected layers, lenticular masses, or chain-like accumulations between the layers of the enclosed formation, giving off sometimes branches which again are accompanied by parallel, lenticular masses or numerous disseminations of graphite through the country rock.

"As to the third class of deposits, that is the disseminated variety, this mode of occurrence is less desirable from the mining point of view than the other two, as described above, since it involves the handling of a very large quantity of rock depending upon the percentage of graphite contained therein, in order to obtain the pure article. Most of the successful mines on the North American continent have been worked on deposits of this character, although the vein occurrences as a rule are of too limited an extent to render their commercial extraction lasting and profitable.

"This disseminated variety occurs as scattered scales or plates through certain portions of gneiss, limestone, or other similar strata; it occurs often in proximity to veins, and in these cases it is supposed that the graphite has hence been distributed along the planes and fissures of the rock in contact, from the vein itself. This has been more particularly observed, where the adjoining rock is a mica gneiss, but similar occurrences are also found in limestone and other rocks belonging to the older series. In the majority of cases disseminated graphite occurs in the neigh-

borhood of eruptive rocks; in fact, some of the richest portions of disseminated graphite have been found near the contact of the country rock with these rocks. It can therefore be reasonably inferred that the presence of these intrusive dikes has had a beneficial influence upon the formation of the deposits in the adjacent strata. Mica schists contain disseminated graphite to such an extent that they become graphitic mica schist.

"From an economic point of view the disseminated graphite is the more important, since it occurs in larger workable deposits, and compared with the vein graphite gives far steadier returns. In the early days of graphite mining, chief attention was paid to graphite occurring in these veins, because it was naturally the purest and most concentrated, and required in the majority of cases little cleaning; but the quantity generally obtained was so small that it did not warrant the expenditure for extensive development-work of these limited and uncertain deposits. To-day all the larger mines obtain their principal output from the disseminated ore bodies, and the chief attention is directed now to the discovery and development of such deposits." *

In the United States, graphite deposits occur in nearly every State, but those of commercial importance are found only in New York, Pennsylvania, Wisconsin, Georgia, Alabama, Michigan, Ohio, Nevada, and North Carolina. Other deposits of less value have been developed in Maine, Montana, New Hampshire, Massachusetts, Rhode Island, Virginia, Arkansas, South Dakota, Wyoming, Colorado, California, and New Mexico. This is indicative of a very wide distribution of the mineral, although not always in large quantities or of high grade, across the middle of the continent.

Of the domestic product, the principal source of supply for the American graphite industry lies in the deposits in Essex and Warren counties, New York. They are situated near the towns of Ticonderoga and Hague, and at Graphite, Dresden, and Whitehall, on both sides of South Bay, an arm of Lake Champlain. The graphite

* Cirkel, "Monograph on Graphite," 22.

is of the crystalline variety and, being mined in almost a pure state, is of the highest value. This is perhaps the most promising district for prospecting and developing graphite properties in the United States. The supply obtained here and elsewhere in America is, however, far from sufficient for all purposes requiring a high grade of graphite, hence large quantities of the mineral are annually imported from Ceylon and Austria.

The graphite at Ticonderoga occurs in minute scales or flakes in the cleavage planes of a seam, in the form of a true fissure, cutting the lamination of the gneissic walls at nearly right angles. The deposits lie between strata of garnetiferous gneiss, micaceous gneiss, and slightly colored quartzite, which are entirely free from graphite. The strata of gneiss dip about twenty degrees south, while the graphite beds, not conforming to this dip, have a low pitch to the east. Kemp believes that this graphite reached the fissure as some volatile or liquid hydrocarbon, and in time became metamorphosed to its present state.*

The Hague vein is divided by a fault, the graphite-bearing quartzite on one side being from one to five feet in thickness, while on the other side it is from two to fifteen feet. There are a mine and a mill in operation on each side of the fault. The vein is thought by some geologists to have been a line of weakness during the geologic upheavals, in evidence of which the ore and wall rocks toward the surface are very much pulverized. Although the ore carries a good percentage of graphite, varying from five to fifteen, the yield is not much more than half the average, or possibly six per cent. From the indications it seems probable that the deepening of the workings will reveal the graphite in coarse flakes in the unaltered rocks, if the faulting has not continued along the vein throughout its course.

* Merrill, "Non-Metallic Minerals," 8.

Walcott describes the deposit at Graphite, four miles west of Hague, N. Y., as of probable organic origin, and occurring in Algonkian rocks.

"At the mines the alternating shale or schist forms a bed varying from 3 to 13 feet in thickness. The outcrop may be traced for a mile or more. The garnetiferous sandstones form a strong ledge above and below the graphite bed. The appearance is that of a fossil coal bed, the alternation having changed the coal to graphite, and the sandstone to indurated, garnetiferous, almost quartzite sandstone. The graphite deposit is here about 9 feet in thickness, and is formed of alternating layers of highly graphitic sandy shale and schist." *

There are other deposits in the Ticonderoga graphite district of which Faxson's, the Jumbo and the Crown Point mines, are perhaps the most promising. The first-named workings are located within a mile of the Dixon mine, and the ore bed is supposed to be a continuation of one or the other of the beds worked by that company. The ore is similar in quality and will probably be worked as successfully as the adjoining one. The Jumbo property is located on Bear Pond Mountain, in the town of Ticonderoga and eleven miles from Crown Point. The prospecting work so far done has been extended over a large area, and the mining done by open pit, the known thickness of the graphitic rock being about one hundred feet. The pits on either side of the mountain are plainly in separate graphite beds, and the natural outcroppings show that almost the whole mountain is composed of quartz-mica schists, and the supply of graphitic rock is unquestionably large. In the Crown Point workings the ore is a graphite-bearing, crystalline limestone, and a second bed has been found three hundred and seventy-five feet south of the main bed. An analysis of a composite sample of this ore showed nearly three per cent of graphitic carbon. As these

* *Bulletin of the Geological Soc. of Am.* X, 1898, 227.

deposits lie near the border of a large area of granite of pre-Cambrian age, and the graphite is evenly distributed through the limestone, it is probable that the carbon formed an original constituent of the limestone. Since graphite is not found in the granite rocks, it is quite evident that it was derived from the carbonaceous constituents of the sedimentary rocks, and has been recrystallized in the contact metamorphism.

Other deposits of crystalline graphite have been mined in the vicinity of Chester Springs, Penn., occurring in richly impregnated beds of mica schist, of which the graphite forms about fifty per cent; at Madrid, Franklin County, and Yarmouth, Cumberland County, Maine; in the vicinity of Custer, South Dakota; in two localities at Stockdale and Taylorsville, Alabama; and in Albemarle and Orange Counties, at the foot of the Blue Ridge, in Virginia.

The occurrence of amorphous graphite is much more frequent in many States of the Union, but the incentive to develop properties containing this variety is much less than in the case of the foliated or flake formation. Because of the lower degree of purity of the amorphous variety, its uses are somewhat limited, and the value of the crude product, as usually obtained, is but one-eighth of that of the flake graphite. In the manufacture of crucibles and for many electrical purposes, no satisfactory material has been discovered as a substitute for crystalline graphite, while in the case of amorphous graphite there are scarcely any of its various uses to which some other substance is not well suited.

In Rhode Island deposits near Cranston have been worked for many years, the mineral here showing a structure between the scaly and the granular. The grade of the product has seldom shown more than fifty-five per cent of carbon, the residue being silica and iron oxide, with a slight trace of sulphur. The vein was discovered in opening up a quarry, and, after it had been exposed

for a distance of more than seventy feet, a shaft was sunk to work it. The bulk of the ore is found in pockets, although it sometimes occurs in fissure veins. In the development of the graphite deposit a vein of semi-anthracite coal has been opened up which, after the purer graphitic portions have been extracted for use as foundry facings, the remainder is used in the furnaces of the Carbon Coal Co., instead of coke, as it possesses peculiar advantages for smelting iron and copper ores.

In Wisconsin, mines near Stevens Point, Portage County, yield an amorphous graphite which has run as high as seventy-four per cent carbon. This product meets a ready demand as a pigment and for lubricants. In Baraga County, Michigan, there are extensive deposits of carbonaceous schist, which is ground up and used in the manufacture of paints. A much more valuable industry, however, is that of the United States Graphite Company, which owns and mines the largest deposit of amorphous graphite yet discovered in America. This is the Santa Maria mine located in the State of Sonora, Mexico, about two hundred miles south of the international line, and about sixty miles east of the Gulf of California. The mining of the ore is carried on with native labor and with considerable difficulty at times; and it is hauled by mule trains thirty-five miles across a desert waste to Torres Station on the Sonora Railway. From here it is shipped more than three thousand miles to the refining plant and manufacturing works of the company in Michigan. The product runs about eighty-five per cent pure carbon, and, because of its high grade, is used for nearly every purpose for which graphite is required, excepting in the manufacture of crucibles, for which the crystalline variety is required.

Some promising deposits have recently been discovered about eight miles southwest of Raton, Colfax County, New Mexico, in which the origin of the graphite is

evident. The whole district is underlaid with bituminous coal in seams varying from three to seven feet in thickness, and, at the place where the graphite is found, a layer of lava has intruded itself above the coal strata. Its great heat has metamorphosed the coal to graphite in a columnar form, which now contains some of the silica originally present in the coal. The occurrence of the graphite is continuous as shown by tunnels driven into the vein where it is cut through by canyons.

Graphite of both varieties has been produced in California, the properties at Sonora being the most important. It has also been observed as outcrops in the Rocky Mountains in Nevada, Utah, Wyoming, and in Chaffee County, Colorado. Other deposits of some economic value are located in Bloomingdale, New Jersey; Clintonville, New York; Salt Sulphur Springs, West Virginia; and there are low-grade ores in Georgia.

In Canada, as in New York State, graphite occurs in Laurentian rocks, both in veins and beds, and of both crystalline and amorphous formations. Some of the veins appear to be true fissure veins, while others evidently are shrinkage cracks or segregation veins traversing the containing rocks in countless numbers. They generally occur in limestone, the granular varieties of the rock often containing large crystalline plates of the mineral, and frequently of a high degree of purity. In other places the substance is so finely disseminated throughout the rock that it gives the limestone a bluish-gray color. It also appears in many of the other rock formations of the vast region. Blocks of graphite have been obtained which weigh as much as fifteen hundred pounds.

The bulk of the graphite produced in Canada is obtained from deposits of the disseminated class, for the best returns have been realized from the scaly, flake graphite in such formations. The most important mines

are situated in Buckingham and Lochaber, about sixteen miles north of Ottawa; at Grenville, Province of Quebec; and in the counties of Leeds, Lanark, Frontenac, and Addington, Province of Ontario; also near St. John, and at King's and Westmoreland counties, Province of New Brunswick; in the Province of Nova Scotia, and at Alkow Harbour, Dean Canal, British Columbia.

The production of graphite in the United States, in 1908, amounted to two million two hundred and eighty-eight thousand pounds, valued at one hundred and thirty-two thousand eight hundred and forty dollars of the crystalline variety, and one thousand four hundred and forty-three short tons, valued at seventy-five thousand two hundred and fifty dollars of the amorphous variety. This shows an average price per pound of the crystalline of five and eight-tenths cents, while the amorphous (reported in tons) was worth fifty-two dollars and fifteen cents per ton. The very low average valuation of the amorphous product in previous years was due to the extreme variation of its purity, the graphite of Alabama and Colorado being of high grade, while that of Georgia is a graphitic schist. As large quantities of the latter are mined at slight cost and sold unrefined at a very low price, the tonnage is greatly increased without adding materially to the total value. In 1908, however, these producers suspended operations, owing to the financial depression, and the amorphous graphite mined in other sections thus shows a nearly true value. The output of New York State is entirely crystalline, or very nearly so, and its value about equals that of both varieties for the rest of the country. To this production must be added the output of artificial graphite manufactured by the International Acheson Co., of Niagara Falls, N. Y. This amounted in 1908, to 7,385,511 pounds, and a value of five hundred and two thousand six hundred and sixty-seven dollars which was six and eight-tenths cents per pound.

The following tables * show in concise form the production of each kind, the valuations, and the imports since 1901, for the United States.

PRODUCTION

Year	Crystalline		Amorphous		Total
	Quantity, pounds	Value	Quantity, short tons	Value	
1901	3,967,612		809		$167,714
1902	3,936,824		4,739		182,108
1903	4,538,155	$154,170	16,591	$ 71,384	225,554
1904	5,681,177	238,447	16,927	82,925	321,372
1905	6,036,567	237,572	21,953	80,639	318,211
1906	5,887,982	238,064	16,853	102,175	340,239
1907	4,947,840	171,149	26,803	125,821	296,970
1908	2,288,000	132,840	1,443	75,250	208,090

IMPORTS

Year	Quantity, short tons	Value
1901	14,325	$ 895,010
1902	18,201	1,168,554
1903	17,298	1,207,700
1904	14,195	905,581
1905	17,457	983,034
1906	25,487	1,554,212
1907	22,939	1,777,389
1908	11,456	762,367

It will thus be seen that the importation into the United States, which is wholly of the crystalline quality, far exceeds the home production in point of value, although the actual tonnage of the mineral is considerably less. It is a noteworthy fact that while this country produces only about ten per cent of the graphite mined

* Compiled from annual reports of U. S. Geol. Sur.

throughout the world, it consumes in the mechanic arts nearly forty per cent of the world's supply.

Graphite as it comes from the earth is seldom, if ever, of a purity to fit it for the uses of commerce; hence it must have more or less treatment of a refining nature. It is said that the now exhausted mines of Cumberland, England, once produced graphite of such purity that small strips were cut from the vein and made into pencils; and it was used for other purposes in its natural state. Such occurrences of pure graphite, in any quantities of economic value, are not found to-day. The only use of the crude material is that made of the crushed graphitic schist of Georgia, in coloring fertilizers.

The increased demand for graphite of the crystalline variety has, through careful study of the ingredients of the various ores, brought about a vast improvement in the methods of purification. Especially is this true of the concentrating and pulverizing of low-grade ores, in which the graphite is disseminated in flakes. One of the most intricate and complex problems in modern ore-dressing lies in the proper separation of the gangue from graphite. The chief difficulty seems to arise from the very close association of the constituent parts of the ore with each other, and from the fact that their specific gravities vary so little. There are two general systems used in America, namely, mechanical separation and chemical refining.

Of the first — separation by mechanical means — there are two methods, the "wet" or water, and the "dry" or air flotation. The wet method is in more general use, especially in the concentration of flake graphite, although many mills use a combination of both methods for the greatest efficiency. The dry method is used quite universally for amorphous graphite, for the reason that, being of granular form, the separation from its impurities is easily effected by air flotation. This is a cheap medium of separation, and the dust is often rich

enough to be packed for shipment direct from the collecting chamber. It also dispenses with special pumping-machinery and the cost of pumping, as well as the drying of the finer products incident to the wet method. There are disadvantages in the latter method in the losses in the tailings, in the difficulty of settling the slimes, and in freezing in cold weather. It will, however, disintegrate earthy and clayey matter, freeing the particles thus cemented together, which the air method will not do. The nature of the ore is, after all, the first consideration in the selection of any means for its reduction.

In the wet method the most efficient crushers are rolls as they have about four times the output of stamps at about twenty mesh. The ball mill is also a good pulverizer of wet graphite ore, and, if designed with large screening area, shows economical results. It combines crushing, elevating and screening operations in one machine. The edge-stone mill is also used for this work.

The second operation, separating the particles of sand of varying degrees of fineness, is accomplished by classifiers. These are funnel-shaped boxes called "spitzkasten," each of different size, so arranged that as the water flows from the first, after depositing the heavier matrix, the next box of larger size spreads it over a greater surface and at less speed, thus leaving finer particles. And so on through the series. Correct width and depth of the boxes is essential to their successful operation, but once these are regulated and the mouth pieces adjusted to the proper flow of the stuff, there is no work to be done.

Buddles of the ordinary circular type serve to concentrate the slimes and fine sediments on a disc inclined toward the periphery. In operation the stuff is supplied through a perforated funnel in the centre of the disc, which is sometimes eighteen or twenty feet in diameter. As it flows out, the smaller particles of higher specific gravity adhere to the surface or move along very slowly

in the current. The larger particles of lower specific gravity propelled by the upper rapid current, move along farther, the surface being swept smooth by two brushes suspended from revolving arms. When the deposit has been built up to the depth of about twelve inches the washing is stopped and the material removed, the particles of different densities being found collected in concentric circles, with the graphite near the periphery of the disc. The products taken off are waste, middlings, and concentrates, in all from fifteen to eighteen tons every ten hours. The middlings are treated a second time on another buddle.

A horizontal revolving sizing sieve is sometimes used for the extraction of flakes, after the classifiers. Brumell's hydraulic separator, or wet box is a concentrator used in the Buckingham graphite district of Canada with good results. Settling tanks are used to precipitate finished products, either concentrates or tailings, from currents of water. The graphite settles in the tanks to a certain height, when the water above is drawn off to waste, and the slime shovelled out. The last tank contains the richest content of graphite, while the first is the weakest. The graphite slime is then treated in filter presses, to separate the water from the solids.

A filter press is a group or series of narrow, flat chambers, formed either by recessed or by flush plates, with frames between them. These plates and frames are provided with lugs on each side about one-third of the way from the top to the bottom. The lugs rest on a pair of parallel bars, the ends of which are firmly set in the strong rigid frame of the press. Over each plate is stretched fine cotton cloth for the filter medium, and the frames are then forced tightly together by means of a heavy screw, or hydraulic plunger in the largest sizes.

The slimes are pumped through a channel in the head of the press, under a pressure of ninety to one hundred pounds, and are distributed over the surface of the filter

medium, the liquid passing through cored channels in the plates, while the solids are retained on the cloth and gradually fill the chambers. The waste water passes out through drip-cocks at the bottom of the frames. The press is then opened, the cakes removed from the frames, and the channels and frames flushed with clean water, when the operation can be repeated. Specially designed pumps, called membrane, or diaphragm, pumps must be used for pumping the slimes. The largest presses have a capacity of from eighteen hundred to twenty-four hundred pounds of graphite in twelve hours.

In the dry method of concentration, the ore, which comes from the mine wet or moist, must be thoroughly dried before treatment. It may be dried by steam pipes connected with an exhaust drum of the steam-power plant, or by direct heat through the medium of a rotary drier, or a natural draft gravity flow drier. The former drier is a cylinder made of boiler plate, thirty to forty feet in length, and from two and one-half to four feet in diameter, set in a brick furnace with only the ends projecting. The cylinder revolves slowly on friction rollers, and the ore within travelling from one end to the other is subjected to great heat of the furnace, by which all the moisture is removed.

The other, or gravity drier is a simple appliance with no mechanical working-parts and has proved very efficient. The principle involved is the utilization of the force of gravity to bring the ore in direct contact with a current of air at high temperature, meeting it in its natural movement upward. The heated gases of the furnace pass directly upward through a flue, through which the ore is supplied from the crusher above. Within the flue, which is inclined at an angle of about forty-five degrees, is a series of steps, and just opposite each is a dam to regulate the supply of ore according to the moisture contained in it. At the bottom of the flue the dried ore passes out and is conveyed to the rock-breakers.

The first crushing of the rock requires a jaw-breaker of large size, in which the jaws, one swinging and the other nearly stationary, are driven by a powerful toggle movement. To pulverize the ore, roll, ball, emery, or buhrstone mills are used, but the pebble tube mill has been quite generally adopted in recent years. It consists of a long cylinder made of boiler plate, from twenty to twenty-five feet long and from four to six feet in diameter, resting on friction rollers, and revolved by spur gear, shaft, and pulley drive. The speed of the revolving cylinder carries the mixture of "hard-heads" or cobble stones and the reduced ore to a certain height within, from which point they fall together, rolling and grinding as the opposing force of gravity draws them downward. Every particle of the material must pass under the grinding action of the whole mass of stones, thus producing a fineness and such uniformity of the output as to render the use of sieves unnecessary. The mill requires little attention, the ore passing in at one end and discharging at the other; and there are no parts to resharpen, little wear and tear, and consequently it is always in running order.

The dry concentration of graphite is more or less of a secret process, as many of the mill-owners have perfected processes best adapted to their own particular needs and requirements, and the appliances used are not shown, nor are the processes divulged. In ordinary use the air jigs and centrifugal concentrators serve the purpose and give satisfactory results when properly handled. Of the former the Krom pneumatic jig is used in many modern graphite-mills because of its simplicity, compactness, and economy of operation.

In principle the machine effects the separation by means of rapid pulsations of air through sieve cloth in the form of oblong tubes, around which the pulverized substance is fed. The graphite is thus forced upward separating from the denser particles, and passes over a tailpiece into

a receiving box. The gangue drops down into another receptacle and is conveyed to the waste. The current of air is supplied by bellows with two hundred and forty to seven hundred and fifty pulsations per minute, and treats from three hundred to six hundred pounds per hour, using but one-eighth of one horse-power. The machine requires constant watching so that the feed may be regular, for if it varies the flake concentrates will be contaminated by the tailings, or there will be loss of concentrates in the tailings. The percentage of graphite in the material varies, too, causing the same losses unless the utmost attention is given.

Other machines are in use, employing the principle of centrifugal force where the particles to be separated are nearly of the same size. The pulverized ore is projected from it with a constant annular velocity. The particles of lower specific gravity, being sooner overcome by atmospheric resistance, quickly fall into one compartment, while others of higher specific gravity pass over and are deposited in another chamber. Still another machine, of which there are two hundred in use in England and America, employs both principles in combination. A rapidly revolving disc from which the powdery substance is thrown causes the centrifugal action, and an air blast from a fan performs the separation much like the air jig.

There are numerous other machines and devices for the operations of both the wet and the dry system, but the ones described seem to be of the greatest efficiency in the refining of most graphite ores, in economical performance and general satisfactory results. The accessories for mills, such as ore bins, feeders, dust fans, screens and sieves, and slime pumps, are arranged to fit the requirements of each plant and locality.

The mines of the Hague vein, in New York State, are opened by adit levels, and the ore is crushed in a battery of stamps of the usual type. After separation by the wet method at the mine it is further refined at the works at

Ticonderoga, and shipped to the manufacturing plant, in Jersey City, N. J., to be worked up into the numerous articles of commerce. At Chester Springs, Penn., the ore is crushed by rolls and then concentrated in log washers. After a further grinding in rolls the graphite is purified by air-blast treatment and sizing screens. The high grade ores of Alabama are subjected to fine crushing and concentrated in settling-tanks.

In Michigan the fine Mexican graphite of the amorphous variety is purified by the air method, and manufactured into various products. In the mill of the North America Graphite Co. the Brumell separator effects the separation by water flotation. Petroleum vapor, which is easily absorbed by the graphite, is introduced, and the light flakes float on the surface, whence they are easily removed. Another method is to heat the ground product before separation, which makes the flakes very light and flotation is facilitated.

The chemical refining of graphite ores is used for reducing certain constituents of the ash, such as oxide of iron, and the silicates, which are intimately associated with graphitic carbon, are then in a fine state of division that they yield to no other treatment. Chemical extraction, if it is to be of practical and universal application, must take into account the constituents of the ash, which change frequently, and add to the difficulties. Numerous methods have been devised to this end, of which one is thus described in a patent specification in 1904:

"The graphite is crushed and passed through a sieve of from 120 to 150 meshes per inch, and then stirred into a saturated solution of alum or aluminum sulphate at a temperature of 212 degrees F. Steatite is then added, and more water if required. After mixing, excess of water is evaporated, until a consistency suited to grinding in a chilled steel or other mixer is obtained. More graphite may here be added; then, after thorough grinding, the material may be compressed into cakes for household use, or is ready for manufacture of pencils, crucibles, and other

articles. Average formula of mixture is: Graphite 80 parts, steatite, soapstone, or talc, 14 parts, alum 6 parts; but this varies with the purpose to which the material is to be applied.

"When several different kinds of graphite have to be employed, the richest in carbon is first mixed into the alum solution. By this process graphites previously regarded as incapable of being compacted are utilized, and are improved in polishing power. For pencils the material may be hard without being brittle, and black without being soft, while crucibles made from the treated graphite are at once harder, more durable and lighter." *

For the production of absolutely pure graphite the method of Brodie is well known. This was briefly described in a foregoing paragraph (page 235). Dr. Donath † has obtained with simple agencies the same results as derived from more complicated processes. Graphites even with a low percentage of carbon, containing from thirty to forty per cent of solid ash, have been raised to ninety-seven and eight-tenths per cent carbon. He uses a treatment with hydrochloric acid, caustic soda, heating with soda, with subsequent washing with hot water.

The uses of graphite are manifold, and it is doubtful if any other mineral enters into more and varied articles of trade. Its characteristics render it peculiarly adapted to purposes for which no other substances are suited, and to others for which its superior qualities are recognized as valuable. But all graphites are not suited to every use to which the mineral is put. A kind which is used most successfully for some purposes may be of far less value or entirely unfit for others, while another graphite will be perfectly suitable for the latter uses. This is not due in every instance to the quality, or the content of carbon in certain graphites, but to the physical condition, whether flake or finely powdered. Amorphous graphite, as an example, can not be used in the manufacture of

* Merrill, "Non-Metallic Minerals," 9.

† Berg & Hutten, "Jahrbuch," 42, 86.

crucibles, although it possesses the same refractory qualities as the crystalline variety, qualities which are essential for that purpose. On the other hand the crystalline graphites can not be used for pencils, at least for the better and high grades; and there are other uses to which the amorphous variety is superior.

Of the world's production of both formations, thirty-five per cent is used in the manufacture of crucibles, retorts, muffles, stirrers, and other articles designed to withstand high temperatures. The great expansion of the steel industry and the development of kindred enterprises on a large scale, within the last fifteen years, has greatly increased the demand for crystalline graphite, and fully fifty-five per cent of this variety is now used for such purposes. It is also of great value in crucibles intended to possess great density at high heat, as in the refining of gold and silver, and to resist the corrosive action of easily oxidized metals and alloys in the molten state, as in melting brass, bronze and so forth.*

The principal materials used in the manufacture of crucibles are graphite, clay, and sand in the proportion of fifty per cent of graphite, thirty-three per cent of clay, and seventeen per cent of sand. These ingredients are combined in such a way that the finished crucible has sufficient density and solidity, and a certain toughness when exposed to fire and the subsequent cooling and reheating. Another important quality is their heat-conducting power; for the heat units needed to melt the metal must pass through the walls of the crucible. Graphite is a good conductor of heat; and because of this quality the charge of a steel-melting graphite crucible is from ninety-five to one hundred and fifteen pounds, while that of a clay crucible is only about sixty pounds. When the former crucible is used the number of heats runs as high as seven or eight in twenty-four hours, as against a possible four heats with a clay crucible in the same time.

* Reports Mines and Quarries, 1902, 1013.

This quality of conductivity of a crucible depends upon the percentage of graphite used in the mixture; but the higher the percentage the more tender is the wall of the crucible, as graphite contributes nothing to its strength. It does add, however, to the life and heat conduction, and is chiefly valuable for supplying the latter quality. To obtain the maximum efficiency, therefore, the mixture must be determined to a nicety for any given class of work.*

"Graphite adds another special quality to the crucible mixture, namely, the ability to stand sudden and severe changes of temperature. On this quality rests mainly the life of the crucible. The ability to stand the strain of passing suddenly from a temperature of 2,000 degrees C., or thereabouts, to 100 C., and then of reversing this, and of doing it repeatedly, is borne by no other crucible material. I have heated a small crucible to about 1,400 C., and then suddenly plunged it into water, returned it to the fire, and repeated this again and again until the crucible had been shocked 20 times. In actual service, where the shock to which the crucible is subjected is not so sudden or severe as that just stated, a crucible has been known to stand from 80 to over 100 charges, though the average life is from 20 to 60 charges when used in melting copper alloys or equivalent metals." †

The one disadvantage in the use of graphite is the decrease of cohesion in the mass when the percentage of the mineral exceeds a certain limit. The proportion of it to the clay must be determined in each special case by exhaustive tests. The selection of the clay is of prime importance, as it must be of the finest and purest quality. Fire-clays are found in every country, but only a few are of the exact composition suited for the manufacture of crucibles. The best clays now used are the Stourbridge clay of England, and the Passau and Klingenberg clay of Bavaria.

Although pencils are of universal use among civilized

* Cirkel, "Monograph on Graphite," 228.

† Downs, in "Iron Age," May 24, 1900, 5.

nations of the earth, and the consumption amounts to many millions yearly, only about four per cent of the world's production of graphite is required in their manufacture. The graphite, however, which enters into the composition of pencil leads, must be pure, it must be susceptible of minute pulverization, and it must be of a nature to unite intimately with the other ingredients. Flake graphite, although possessing the first requisite, is incapable of fine pulverization with evenness of grain, which is absolutely essential in pencils of the highest grade. It would yield a "lead" that would slip over the paper, leaving only a faint streak. Nor is artificial graphite possible in the production of a satisfactory pencil; for, though amorphous in nature, it seems to lack uniformity and to contain some grit. Man, ingenious as he is in the control of electrical forces, can not transform coal into as perfect graphite for this purpose, as is produced in Nature's laboratory.

Amorphous graphite in its nearly pure state as produced from a few deposits, is capable of reduction to impalpable and gritless fineness, and combines readily with the clays which enter into the mixture of pencil leads. Because this graphite product is so sensitive to impurities and lack of uniformity in the mineral, the best quality is obtained only from the mines in Mexico, Siberia, Bohemia, and Ceylon.

During the last fifteen years fully eighty per cent of the world's pencil graphite has been taken from one mine in the State of Sonora, Mexico. The famous Alibert mine in Siberia, supplies the bulk of the foreign trade which is centred in Nuremberg, Germany, where are located twenty-six pencil factories, among them the well-known Faber works. For a century preceding 1890 the district of Nuremberg was considered the headquarters of the pencil industry of the world. With the mining of the Mexican graphite and its use in the manufacture of pencils in the United States, the imports of this article

fell off nearly one-half in three years, and has been gradually declining ever since. On the other hand, this country has become a large exporter of pencils, while to-day, fully nine-tenths of the pencils used in America are of home manufacture. The pencil factories of the United States employ more than two thousand people, who earn about seven hundred thousand dollars yearly, producing pencils and the allied articles to the value of two million dollars.

The methods of preparing the pencil leads have undergone many changes since the opening of the graphite beds in Cumberland, England, in the reign of Queen Elizabeth. In those times the graphite was mined in a state of such purity, that the large blocks obtained were simply sawed into sheets and again into strips, and these were inserted in wooden handles. To-day the mineral passes through various processes of purification, is then ground into a powder of impalpable fineness, and after further grinding with clay, is compressed into the "lead." For the softer grades little clay is associated with the graphite, while for harder pencils, more clay enters into the mixture, according to the degree of hardness desired.

Of the quantitative proportions, every manufacturer has his own standard formula, which is dependent to a certain degree upon the quality of the material employed. For pencils intended for universal use in the office or for general purposes a mixture of two parts in weight of graphite to three parts of clay, or even quantities of each, is much used. One manufacturer uses thirty parts of graphite, nine parts of clay, nine parts of gray antimony, and one part of tallow. Very hard pencils for drawing purpose are made of the following mixture: twenty-six parts of graphite, sixteen parts of clay, eight parts of antimony, and two parts of lampblack. This last ingredient is used to add color and lustre to the marking quality.

The very characteristics which unfit the true crystalline

or flake graphite for use in pencils, seem to unite in making it peculiarly suited for the purposes of lubrication. Composed as it is of countless minute flakes of extreme thinness and flexibility, which cover and adhere to rough metal surfaces as a high polish, it reduces friction between the bearings to a remarkable degree. Being a solid or dry lubricant it is generally applied mixed with the lubricating oils, greases, or even with water in some instances. In the case of light bearings or of machinery where oil may soil delicate textiles, graphite can be used alone.

It is valuable, and is used for all kinds of heavy machinery, as it withstands the greatest pressures; and it is used for fast-running journals, as it is a cooling agent through its low coefficient of friction and resistance to high temperatures. Through scientific tests the Ticonderoga flake graphite has been shown to be unexcelled for all purposes of lubrication, but the fine amorphous quality from the Mexican mine is also largely used for the same purposes. Of both varieties about sixteen per cent of the world's production is used as a lubricant.

The chief function of a lubricant is to overcome friction, and oils and greases are supposed to form a thin film between the bearings, thus preventing a metal-to-metal contact. But all wearing surfaces, either of journals, engine cylinders, or sliding planes, no matter how smoothly finished, reveal under the microscope minute irregularities, depressions and elevations beyond the normal line. The application of graphite with the lubricating oil tends to even out these more or less rough surfaces, and thus aids in maintaining cool and smooth-running bearings.

Flake graphite does this by simply adhering to the surfaces, the flakes overlapping one another and forming a thin veneer, so that the oil will subdivide in a movement within itself, and not between it and the metal.

Amorphous graphite, being a finely divided powder, enters more intimately into the pores and structural irregularities of the metal surfaces, and, as it withstands great pressure, builds up the minute hollows and buffs off the tops. However, it wears away rather quickly, rendering constant application necessary. It is held in suspension in the oil, so that each drop as delivered by specially designed lubricators, carries its mite of graphite to the desired point.

"The oil meanwhile serves its purpose as an intermediate film and, because of the finish which is given the surfaces by the graphite, the duty imposed upon the oil is reduced, the action of the film becomes more efficient, and the necessity for the renewal of the oil less frequent. Where graphite is continuously supplied to a bearing, there must be some particles in the film of oil, but the presence of these, intermixed and moving with the oil film, does not increase the efficiency of the mixture lubricating process. It is only when the graphite has separated from the oil and found lodgment upon the metal surfaces that it becomes effective.

"By the use of graphite, water (under favorable conditions) may serve as a sufficient lubricant. It is entirely logical to assume that the preparation of the surfaces of a bearing may be so complete that not only limpid oils, but even water, may suffice for their lubrication. Confirmation of this comes from the engine room where, in the cylinders of steam engines, graphite has come to be extensively employed unmixed with other lubricants. In this service, the currents of steam and films of moisture which extend themselves over the rubbing surfaces serve as a sufficient vehicle for carrying the flake graphite forward and distributing it over the surfaces to be lubricated, and the water of condensation serves as the intervening film, with results which are as important as they have been satisfactory. Engines which have required large quantities of cylinder oil are now running on small quantities of graphite.

"A small quantity of graphite only is required. That the amount need never be relatively great is apparent when it is remembered that the purpose of the supply is merely to maintain

against natural wear the graphite coating on the surfaces in contact. The supply of too much graphite increases journal friction, as it unduly thickens the liquid oil." *

As a pigment graphite serves a most useful purpose, and is unequalled for covering metal surfaces exposed to severe climatic conditions, or to water, steam, acids, sulphur fumes, smoke, or any corrosive action. Its natural affinity for oil, its density, and its remarkable covering power and durability, are other properties that give economic value to paint. Good graphite paint, as made from the pure amorphous graphite, or from certain flake graphites susceptible of fine pulverization, is used very largely in covering the steel structure of buildings, railway equipment and buildings, steam vessels and barges, gas-holders, factory buildings and roofs, machinery, and all surfaces subject to chemical action. For all such purposes about three per cent of the world's output of graphite is used annually, the amorphous variety being the chief source of supply.

Flake graphite, when ground to the finest degree possible still retains its laminated, crystalline structure and, however thoroughly ground in linseed oil, there are ever present in the paint film countless scale-like flakes protruding their minute sharp edges, thus creating a somewhat porous surface. This may absorb moisture and destructive gases which in time will penetrate to and corrode the metal which it was desired to protect. The amorphous graphite, being an impalpably fine powder, is more easily applied when purified and ground in pure linseed oil; besides, it covers much more surface, and leaves a smooth hard film, but surprisingly elastic. The standard amorphous graphite paint contains more linseed oil, a greater proportion of graphitic carbon, and a very much smaller quantity of silica, than the standard flake graphite paint. The latter contains nearly as much silica as

* Goss, "Study in Graphite," 10.

graphite; while another make when analyzed, showed five per cent more of silica. A certain amount of silica, however, is believed to give a quality of permanence. The amorphous graphite paint, moreover, contains little of the oxides and none of the resinates or rosin, while the flake graphite paint includes as much as thirteen per cent of such constituents.

Graphite as a foundry facing, is put on the surface of a mould for the purpose of preventing the sand of which the mould is composed from adhering to the metal. A graphite facing saves cleaning of the castings, gives smoother castings, facilitates machine work, and is more economical in every respect than preparations of charcoal or talc. It accomplishes these results by forming between the surface of the mould and the molten metal a thin film of gas by its slow combustion; and this continues during the entire time the metal is in the fluid state. The conditions existing in different foundries are so varied as to require facings of various composition for special purposes. Amorphous graphite is more largely used for such work, the consumption of both kinds being about ten per cent of the total production of graphite.*

About fifteen per cent of the yearly output of graphite is used in the manufacture of stove polish, first called when introduced in 1827, "carburet of iron," for the reason that it was supposed to be a compound of carbon and iron. The polish actually contains no iron, but it prevents rust to iron surfaces, and imparts a bright lustre when vigorously rubbed. It is supplied to commerce in the form of thick paste, consisting of benzin, some oil or soap, and finely powdered graphite; it is sold also in the form of cakes which generally represent a certain refinement of the product.

Within the last ten years graphite has become a useful

*Dixon's Graphite Prod.

article in the electrical industry, the remarkable expansion of which calls for increasing amounts in the making of commutator brushes. For this purpose its conductivity, smoothness, and lubricating qualities are of much value, the friction on the commutator is less than with carbon brushes, and the commutator is automatically lubricated. The vibration of the generators and the design of the brush-holder are very important variable elements, and the brush pressure is also a factor in the successful use of graphite brushes. Artificial graphite is very largely used for this purpose. It also finds a use as a packing material for delicate electric lamp filaments.

Graphite of a fine scaly quality is used in electrotyping in which it is valuable on account of its great electrical conductivity. Flake graphite is used as a polishing and protective covering to gunpowder; a more unusual application, perhaps, is to color and glaze both tea leaves and coffee beans. It protects these against moisture; it adds to their attractiveness; and it is absolutely harmless. The impure earthy graphite of Georgia is used almost entirely to color fertilizers.

Some minor uses of graphite are, as a pipe cement, a belt and cable dressing, piano-action finish, and stove and boiler cement. It can also be used as a preventive of boiler scale by simply injecting a very small quantity of graphite in the feed water. Further deposition of scale is thus prevented, and it will even cause the old scale to soften and peel off. After several months the inside of the boiler shell and the tubes will be bright and clean. The use of graphite in engine cylinders as a lubricant, where the condensation is passed back to the boiler as feed water, led to this discovery.

Since the process employed by man in making artificial graphite is, beyond doubt, a duplication of Nature's method of forming the natural graphites of the earth, the present treatment of this subject should include some mention of the former.

"The manufacture of artificial graphite is one of the surprising and wonderful processes of Niagara Falls. The furnace is of boxlike construction, with a very refractory lining, outside of which are refractory brick loosely placed. The raw material used is anthracite coal. When a furnace has been charged with the raw material the electric current is thrown on, and 1,000 electrical horse-power is applied to the operation of the furnace. For many hours this large amount of power is gradually converted into heat energy, the heat being retained in the furnace without radiation. Thus it gradually accumulates until the temperature of the furnace reaches an almost unknown value. At this point the anthracite coal is converted into graphite.

"It is probable that in the electric furnace the highest temperature known to man is to be found, even going beyond 7,500 degrees Fahrenheit. At this temperature all substances other than carbon are volatilized and are driven from the furnace like so much moisture or vapor. It is thus evident that graphite formed in this manner, and in such a remarkable temperature, is very pure. The uniform quality of the product has commanded attention. It could hardly be otherwise, for the raw material used is always uniform, and the process of manufacture is under absolute control from the moment the electrical current is turned on until it is cut off." *

The discovery of artificial graphite was made by E. G. Acheson, in the manufacture of carborundum, which is a product of the electric furnace. In operating these furnaces he found a layer of bright graphite lying between the crystalline carborundum and the core. Upon examination it was found to be formed by the decomposition of the carborundum itself. The grains composing the core also were changed, they were softer, would mark paper like a pencil, and upon rubbing left a polished surface. They showed high conductivity of heat and electricity, and were nearly chemically pure. Some were dull black of great hardness, while others were of the soft brilliant variety, the difference being due to the ash content of the various cokes used in the process. From

* *Harper's Weekly*, Oct. 1, 1904, 1512.

these observations, Mr. Acheson concluded that graphite might be made in commercial quantities by a general method of decomposition of carbides.

"I have also discovered that in order to produce pure graphite from carbonaceous materials there is an indirect conversion, and that the act of formation of the graphite is more in the nature of an act of disassociation of the carbon from its combination with other materials, than a conversion of the ordinary carbon into graphite, and that as a preliminary step the carbon has to be combined chemically with some other material. Thus I have found that if the carbonaceous material or carbon used in the process contains a considerable proportion of mineral matter, or if it is mixed with a certain proportion of oxide or oxides, such as silica, clay, alumina, magnesia, lime, or oxide of iron, the yield of graphite is enormously increased and the product is more satisfactory." *

"It followed almost as a matter of course that the conversion of carbon into graphite by any method of electrical heating depended upon the presence in the carbon of carbide-producing elements. It likewise followed that the impurities should be present only in such quantities as to permit the progressive transformation of the mass of coke into graphite, carbides being formed and decomposed, the volatilized non-carbon element combining with adjacent portions of the carbon. Mr. Acheson found an artificial mixture of carbon with impurities was unnecessary, since non-coking coals and certain varieties of charcoal contain the proper minerals. As the last patent states, the original distribution of volatile impurities is important. For example, petroleum coke, in the form of lumps and in rough admixtures of iron, or iron ore, can be suitably heated in an electrical furnace, thereby causing the vapors of the metal so to permeate the entire mass as to determine its complete transformation into graphite." †

Until 1891 the conversion of carbon into graphite had been accomplished by a heating current alone, but at that time a process was discovered in Stockholm, whereby, with the simultaneous use of a high tension

* U. S. Patent, 568, 323, Sept. 29, 1896.

† "*Sci. Am.*," Dec. 13, 1902, 225–230.

alternating current of high frequency, and a heating current of the usual kind, the conversion proceeded much more rapidly. The high tension alternating current produces very rapid ether-vibrations, which seem to influence the molecular alteration of the carbon pieces under treatment. To prevent the combustion of these pieces the operation is conducted in an exhausted chamber, so that there will be no access of air to the glowing carbon. These experiments naturally raise the question whether or not the natural graphites of the earth were formed by heat alone, or if some other element of an electrical nature entered into the process.

In 1906 Mr. Acheson, after further research and experiment, discovered a means of producing a soft, unctuous graphite to add to his useful products. Before this the graphite manufactured was of a hard granular or powdered kind and was used chiefly for various purposes in the electrical industry. The new output opened up a broader field for artificial graphite, and it may now be used to advantage in lubricants, paints, electrotypers' work, and as a stove polish. As it is produced at a comparatively low cost from anthracite coal the soft graphite is becoming a successful competitor of the natural graphites.

The production of artificial graphite in 1902 was 2,358,828 pounds, valued at one hundred and ten thousand six hundred and twenty-nine dollars, or four and sixty-nine hundredths cents per pound. By 1904 it had increased to 3,248,000 pounds of a valuation of two hundred and seventeen thousand seven hundred and ninety dollars, or six and seven-tenths cents per pound. In 1905 the production reached 4,591,550 pounds valued at three hundred and thirteen thousand nine hundred and eighty dollars, or six and eighty-four hundredths cents per pound. In 1908 it reached 7,385,511 pounds, of a value five hundred and two thousand six hundred and sixty-seven dollars, or six and eight-tenths

cents per pound. Graphite thus artificially produced in an electric furnace is a wonderful substance; but with all its possibilities, there seem to be certain purposes for which no other than the natural graphite of the crystalline or the fine amorphous variety, will do as well.

IX

SIGHTLESS WORKERS

THE ACHIEVEMENTS OF THE BLIND

THE MICHIGAN EMPLOYMENT INSTITUTION FOR THE ADULT BLIND — CAUSE OF ITS BEING ESTABLISHED — SCOPE OF THE TRADES SCHOOL — EXAMPLES OF ITS SUCCESSFUL PUPILS — INMATES BECOME WAGE-EARNERS — DAILY ROUTINE — BROOM-MAKING — FEATHER-DUSTER-MAKING — WORK OF BLIND WOMEN — THE LIBRARY FOR THE BLIND — RECREATIONS.

POINTING out to the maimed, the halt, the blind, and those otherwise incapacitated for the active duties of life, greater hope and a plane of more useful lives, is a splendid work, and is being recognized as a worthy function of State Government. The loss of any one of the five senses, or of any faculty, is a great affliction, but to be entirely deprived of sight is most distressing, and casts the unfortunate one into the very depths of despair. With little or no prospect of relief, life has little hope, for the flame of ambition — the joy of progress — has been extinguished. The weeks and months draw along miserably until mere existence becomes a burden. The suffering and discontent of the afflicted often bear heavily on the happiness of the family life, while constant brooding over the perversity of fate frequently affects the mental faculties, and threatens insanity unless the entire train of thought be diverted.

Great progress is being made in teaching sightless persons, both women and men, how to earn a comfortable living; and, by surrounding them with uplifting influences, both moral and intellectual, their lot, at least in several States, is being raised from one of mere existence to that

of the self-respecting citizen. And under the best conditions, where the highest interests of the blind are matters of personal concern by the institutional management, they enjoy in some degree the harmless recreations and pleasures that life offers their more fortunate brothers. Self-interest, contentment, and cheerfulness supplant the depression which weighed on them so heavily; and, after their apprenticeship is ended, they return to their homes in a hopeful frame of mind and follow their chosen occupation, once more useful citizens. A State institution, which is a model of its kind and which is not dominated by political influences, is the Michigan Employment Institution for the Adult Blind.

It frequently happens that the most worthy and beneficial movements of State initiative, and which are of great economic and educational value, are so little heralded, and when brought to a successful issue are so quietly conducted, that few people of the State in which the institutions exist have more than a superficial knowledge of them. The movement in aid of sightless adults, who have been afflicted after attaining the age of 18, is of this kind. It is a broad movement, nevertheless, and it is a happy augury of the extension of the good work, that an awakened public conscience is quietly yet effectively working with the liberal-minded legislators of the leading States, to the end that they are giving it deeper thought and more hearty support. The subject is one that appeals to all sympathetic people who give it study and thought.

More than fifty years ago — in 1854, to be exact, and during the governorship of Andrew Parsons — the State of Michigan first gave its aid in a practical way to the education of its juvenile blind. The early legislative enactment provided meagrely for such an institution, as the State was in the formative period; but, as population increased and the needs became greater, more liberal appropriations for extension of the work were made, and

the movement came to be recognized as a public utility. It started in a small way, the institution being connected with the school for deaf mutes at Flint, where the course of study and training for the blind under 18 years of age, was carried on successfully for some years. By 1880, however, the institutions had so outgrown the accommodations of buildings and grounds, that the State separated them, removing the blind school to Lansing, the State capital, and there established it on a firm and enduring basis, financial and instructive. The curriculum of this school for blind children is liberal in providing instruction of practical use in later life, including a full high-school course, and the manual training is most thorough. The Emeritus Principal of the institution says:

"In the education of blind children, while we endeavor by a course of study to put them as nearly as possible on an equality, so far as general culture is concerned, with seeing people, we cannot, for example, give them laboratory instruction in chemistry or biology, and similar limitations obtain in the case of most of the physical sciences. What they know of these they must learn from information rather than from personal research. Languages, on the other hand, present fewer difficulties, and some of the great successes of the blind have been in these fields. Many show a peculiar aptitude for mathematics. Intelligent blind children are usually more proficient in simple arithmetical calculations than those of an equal age and general attainments who can see. This is largely due to the fact that the blind (whose multiplication table goes up to 12 times 25) are much more exercised in mental calculations than normal children, who depend so much upon 'doing sums' on paper.

"Probably the most noteworthy example of mathematical proficiency in a blind person trained under modern methods is Louis B. Carll, fellow of Columbia University, and the author of a treatise on higher mathematics. He was born blind, had his preliminary education in the New York Institution, and was graduated second in his class in the university. No other blind mathematician of such ability has been developed since the time of Nicholas Saunderson who, in the early part of the eighteenth cen-

tury, was a Cambridge professor of mathematics and lectured on hydrostatics, mechanics, astronomy, tides, and optics, and of whom Lord Chesterfield, who was one of his pupils, said, that he had not the use of his own eyes, but taught others to use theirs."

Almost from the beginning of the measures to provide for the education of its blind people, it was foreseen that all of them could not follow professional pursuits. The sightless are not confined to one class or condition in life, they include the laborer, the artisan, the tradesman, the skilled mechanic, and the college-bred man. This is true of women as well as men. It was necessary, therefore, to make provision for industrial as well as intellectual training. In the school established at Flint and later removed to Lansing, industrial trades had been introduced in a small way; and it was early discovered that many persons who had lost their sight after becoming adults were very anxious to be taught some industrial occupation. Among those who had been thus trained at the school for the blind, many wished the school to continue to employ them, saying that they were unable either to start in business for themselves, or to secure employment in shops with sighted help. The Lansing school at first tried to meet this demand; but the endeavor could at best benefit only a few of the many who needed such aid. At length it so imperilled the usefulness of the school as an institution for the moral and intellectual education of the youthful blind, and also resulted in such financial loss, that this effort to assist the older blind was entirely discontinued.

After several years of agitation, more or less intermittent, the Michigan Employment Institution for the Adult Blind was established in 1903, during the administration of Governor Aaron T. Bliss, who gave it his hearty support, and considered the opening of the institution in December, 1904, the culmination of his official life. The institution is located in Saginaw,

the ex-governor's home city, and the buildings face Bliss Park, which was one of his many benefactions. There are four main buildings, the middle one of the group being the Administration building, the dormitories, one for men and the other for women, being widely separated on each side; while the factory, heating plant, and warehouse are situated directly behind the administration building. The structures are built of vitrified brick with cut-stone trimmings, and arranged with special regard to the peculiar requirements of sightless people. The administration building contains the offices and vaults of the institution, reception rooms, the State circulating library for the blind, the chapel, and the living-rooms of the Superintendent.

As all real happiness in this life is founded on productive effort — work which results in some good — the keystone of this institution is Industry. It is a trades-school, pure and simple, as opposed to the poorhouse or home, and receives totally blind and partially blind people between the ages of eighteen and sixty. If a man is not capable of learning the simplest trade taught, so that he can earn enough wages for his living, the institution cannot keep him after his apprenticeship is ended. This the State has placed at three years. So far, no sightless person has failed to meet this easy requirement, and many men have learned a self-supporting trade in six months to a year, and returned to their homes to follow it.

The idea of giving the adult blind a practical education and manual training, instead of maintaining them in idleness in other public institutions, is not new, but has been applied along industrial lines only within very recent years. The work, necessarily, is yet in its infancy, and is capable of much development. As a mere matter of fact, the blind who need help, like any other class demanding aid, could doubtless be taken care of more cheaply in poorhouses or other places where no attention need be given to teaching trades. But if we take

into consideration the renewed hope, the regained usefulness and the brightened lives made possible by such institutions, they *are* a necessity. There are nearly three thousand blind people in the State of Michigan, out of about seventy thousand in the entire country, and of these a large proportion lost their sight in adult age, usually from accident or disease. A large number of the afflicted come from the upper peninsula of the State, where mining is extensively carried on, an occupation of extreme hazard.

But the adult blind who, through accident, abuse, or neglect, are stricken after the habits of life are formed, and a life profession or trade mastered, are in even greater need of aid and encouragement in their efforts to become again self-supporting. In this work this institution proves a saving grace. "What can a blind man or woman do for a living?" is often asked the Superintendent and others interested in the work. The question is easily answered in a logical way by a clear enumeration of the fields of activity from which the blind are debarred from the nature of their affliction. And this discloses the fact that training must necessarily be limited to the teaching of those occupations in which they will be least at a disadvantage with seeing competitors. The result of this rational system of practical education is that, of the total blind in the United States, fully fifteen thousand are in whole or in part self-supporting.

"They cannot, of course, engage profitably in most callings which require quickness and coördination of sight with the other faculties. Thus most of the mechanical trades are closed to them, and also general mercantile pursuits." Still some opportunities exist in business, which appeal to energetic and ambitious blind people, and progress is being made in perfecting a special commercial course, in addition to the literary, musical, and manual training afforded. The net result of this work is very complimentary to the management of the institution, and

FEATHER-DUSTER FACTORY, BLIND INSTITUTION, MICHIGAN

UNIV. OF
CALIFORNIA

BASKET WORKER, BLIND INSTITUTION, MICHIGAN

all graduates, so far as known, are succeeding in their vocations.

One blind man, who was formerly superintendent of the blind institution, conducts a large piano business in Grand Rapids; and his chief salesman, also blind, received his training for this work in the institution. Several others took up piano-tuning, and are getting all the work they can do, while two others, who showed special aptitude for mechanics, have good positions in a New York piano factory. Another case of a mechanic who lost his sight by accident in a shop, when well along in years, is interesting as showing remarkable fortitude, perseverance, and patience. The man learned the broom trade, from the making to the retailing; then, returning after several months to his home in Detroit, he set out to establish a regular trade among the grocery stores and shops, and was soon taking orders of from one to twenty dozen brooms, and earning from five to fifteen dollars a week. One blind man has a newspaper stand and magazine agency, together with a stock of tobacco and cigars, which he has conducted for a number of years, and has always done well. His customers are legion, and of a class that would not take the slightest advantage of him, even if it were possible.

A foreman in one of the large copper and brass rolling-mills in Detroit, lost his sight a few years ago by an accident in the shop. For three years he was at home nearly helpless, scarcely able to feed and dress himself. Hearing of the institution soon after it was opened, friends wrote asking to have him admitted. He came on February 6, 1905, and stayed until May 27 of the same year. During that time he learned to use the typewriter, to read and write by the Braille or point system, and made a good start at learning the broom trade. Being a man of business instincts and too old ever to work rapidly at the broom trade, he was advised to try selling brooms. He is now self-supporting and a self-respecting citizen,

earning enough to care for himself comfortably. From one of his letters we quote this extract, none the less effective for its German form of expression:

"Mr. Hamilton, I can never you enough thank for what the institution has done for me. I owe it everything. I am again a man and of some use in the world. I do not more make my people unhappy, as I am now content."

Some time after this, J. S. was brought from a county poorhouse. He is doubly afflicted, being both deaf and dumb and blind. Since entering the institution he has learned to sew brooms, cane chairs, use the typewriter well, and is one of the happiest, most contented men there. The attendants and some of the inmates talk to him by using the deaf-and-dumb alphabet. He simply puts his hand on that of the talker, and in this way conversation can be carried on quite rapidly; and explanations made are generally understood. Recently another deaf and dumb and blind man was admitted, and S. took him in charge to teach him the way about the buildings. Each seemed happy to have met the other, and they have been of mutual benefit.

Of the blind people engaged in gainful pursuits in the United States, a large proportion are farmers. Nearly six thousand are following agriculture, and this is explained by the fact that the manual labor involved in such operations is not attended with much risk of injury, and a strong, active blind man can easily learn the routine of such work, no part of which, for obvious reasons, enters into the training-courses of the institution. There are enough other occupations to be taught, which offer the blind greater freedom of action and more opportunities of advancement, and also allow recreations so necessary to the afflicted, but not afforded by farm life.

The problem of finding work for the women and girls is more difficult, but the institution is doing what it can to find profitable occupations for them. Several are employed in

the institution. The visitors' attendant is a blind girl, and she shows people around the buildings so fearlessly that many refuse to believe that she is entirely blind. The seamstress is a blind girl, and does all the mending and making of table-cloths, napkins, pillow-cases, and sheets, using a sewing machine as well as any of her sighted sisters. Since a blind girl was secured to do the dish-washing, the work has always been satisfactory.

Besides totally blind persons, those partially blind are also admitted to the institution. But a person with some sight is a less efficient worker than one entirely blind, and, strange as it may seem, he is a far less rapid operator. The reason for this is, one who is not entirely sightless sees objects very imperfectly, nearly all detail and even the general outlines fading away in dimness and haziness; but still, from force of habit or from inclination to cling to the use of the eyesight so long as it remains, the worker depends on the failing sight, while the entirely blind rely only on the sense of touch, which soon, from constant use far more exacting than with sighted people, becomes very keen and sensitive.

The apprentices, who always form the major part of the enrollment, as it is intended they shall, are allowed their board, lodging, washing, and instruction; and, after a trade has been learned they become wage-workers if they care to remain. They are then put on the payroll, and paid by the piece at current wage rates. The policy of the institution in this matter is to pay rates which are just and reasonable, but at the same time not high enough to be too great an incentive to the workers to remain indefinitely, after they have become skilled in their trades, and can earn as much or more outside. The institution is primarily a trades-school, and is intended as a permanent home only to those who by reason of other disability or age can never be self-supporting elsewhere. If the workers continue living in the institution, which is optional, they begin at once paying for their board, lodg-

ing, and minor expenses, at the nominal rate of two dollars and a half a week. At this rate, which is about the actual cost, the slowest worker has earned above his living about one dollar in a month, while the skilled and rapid operator has cleared above his living from twenty-five to thirty dollars in the same time. There are about one hundred inmates in the institution during the greater portion of the year, of whom about seventy are men. This disparity is due to the fact that the problem of how best to care for and give profitable employment to blind women, has not been solved. New industries are being introduced, but the difficulty seems to be in finding occupations adapted to women's strength and endurance, at which they can work rapidly enough to be self-supporting, and which they can follow when they return to their homes. A few of the inmates are employed in sorting broom corn, or selecting feathers for duster-making, besides those who are engaged in the direct work of the institution.

The shops are operated strictly on business principles, and the discipline of the workers is excellent and most commendable. Rules and regulations, ironbound, yet free from a suspicion of oppression, operate to the highest good of the institution's family. At six in the morning all the inmates are awake, and busily preparing themselves for the duties of the day. Fifteen minutes later they are ready for the morning meal and, as they feel their way along the broad stone walks from the dormitories to the mess hall in the high and airy basement of the administration building, they present as clean and neat appearance as will be found anywhere among factory workers. Care in these particulars is one of the requirements, and every convenience and facility is afforded to forward this end. At five minutes to seven the first working whistle sounds, and at seven another double blast brings all hands into activity. At eleven-thirty, when half of the day's work has been done, the

workers " ring-off " for dinner and a semi-social time, and at no time of the day are the cheer and good fellowship more in evidence. The *menu* is made up of plain and wholesome food, well cooked and served in abundant quantity; and, the principal items being changed from day to day, it seems to fill the requirements perfectly.

At one o'clock the workers are again at their tasks, each individual silently but contentedly performing the particular work assigned to him. In the end many different articles of everyday use in the household are made for the market, and the revenue from the sale of such products goes a long way toward meeting the expenses of the institution. When the five-thirty whistle blows the sightless workers have rounded out nine hours of profitable work, and they are free for the rest of the day. No one is encouraged in the idea of working overtime, in order to swell his earnings, but instead, to pass the time in which free instruction is offered, in reading of the Braille system; and those not already proficient in that most consoling accomplishment of the blind, avail themselves of the privilege. Typewriting, and the use of the wonderful little machine which writes a raised print from the English Braille, are also taught, while the State Library for the Blind, housed in the administration building, is open to the inmates.

After the evening meal, those who care for the news of the day throughout the world meet in the assembly hall, where the daily city papers are read aloud, and other entertainment is given. Concerts, lectures, readings, and social gatherings, to which the blind of the town outside of the institution are invited, are frequently given. On Sunday afternoon, there are religious services in the chapel, conducted by clergy of different denominations. At ten o'clock the routine of the institution comes to an end; the dormitories are quiet, and the dwellers of this outer world of darkness are taking their well-earned rest.

From time immemorial broom-making has been the

chief occupation for blind men, and in the Michigan Institution it forms the principal trade taught. This must always be so because a considerable number of blind men elect to remain as wage-workers in the institution, and some steady and profitable work must be given them at all times. There is always a ready market for brooms of different grades and sizes, including whisk brooms, and the making of them is simple and well adapted to hand-work. Many blind men take to it instinctively and soon become proficient workers. The broom shop occupies the entire lower floor of the factory, and at times it is much overcrowded. As nearly all the work is done by hand, very little machinery is used, and it is of the simplest kind. Each apprentice learns every process in the making of a broom, so as to be able to make one completely; but when he becomes skilled in the whole operation he generally chooses some particular process in which he is the most adept. In this practice the wage-workers become rapid operators, and the output of the shop is greatly increased.

The broom corn as it comes in bales from Oklahoma and other Western States, is of a light yellow color. To prepare it for use it is dyed a light green and then put through a bleaching process which gives the broom the bright clean appearance so much desired by the housewife. The stock then goes to the shop and is placed on long tables, where it is sorted to lengths by measured strips of wood, and arranged in racks. The largest pieces, called the hurl, are cut off at the joint and used for the outside of the broom, while the shorter pieces, or clippings, form the inside or packing. The stems are picked out by other apprentices, as they would spoil a good broom. The sorted stock is taken as needed to the broom-making side of the shop, where the winding and sewing operations are done by the more skilled and experienced workers.

In the winding of a broom the short stalks are first

WINDING DUSTERS, BLIND INSTITUTION, MICHIGAN

COBBLERS' ROOM, MICHIGAN BLIND INSTITUTION

bound to the handle by wire under heavy tension, to form the shoulder, or flaring solid part. Longer pieces are then put on and finally the hurl or covering is locked on by the continuous strands of wire at the top. Being worked up wet, the stalks are pliable and easily shaped to the desired form. The sewing is done rapidly, and the accuracy and precision with which the blind workers use their fingers for eyes, is astonishing. One of the sewers is also deaf and dumb but despite his double affliction, he is one of the most cheerful men in the shop. His other faculties seem to be acutely attuned to every sensation, to every vibrant pulse of the shop, for when the superintendent enters, that fact is instinctively borne to him. With less fine perception the other sightless ones determine the same fact by the distinguishing footfalls of his step. This blind and deaf and dumb man recognizes his friends by passing his hands quickly over the face, with a light and hardly perceptible touch. He converses with the foreman and with other inmates thus afflicted, by the use of the double-handed alphabet of the dumb. They simply take hands and the reader with his fingers follows the motions of the other's hands, conversation being thus carried on quite smoothly. After the brooms have been passed on to still other workers, who clip off the ends evenly to the proper length, they are allowed to dry for twenty-four hours. They are then packed in bundles and stored ready to fill orders from the home market and outside.

Feather-duster making is the second industry in importance; about fifteen different kinds of dusters are manufactured, from the gilt-edged affair with yellow feathers handsomely striped and tinted with delicate colors, to the common cheap sort for ordinary, everyday use. The materials are turkey feathers, which come in bales from Chicago, black-enamelled and natural wood handles, and spools of wire. The feathers as received are wrinkled and matted together; and to make them fit for use they are

sprinkled with water and placed in a large revolving drum or "tumbler." After whirling about in this machine for a time, they are taken out straight, shining and perfect in form. They are then sorted to lengths, the different divisions on the measuring board being indicated by little brass knobs, which the operators feel.

In their natural state the feathers are too stiff to make good dusters; to correct this they are drawn through a machine, the knife of which splits the quills in two. To render them still more pliable another machine rasps the quills, which removes the pith, leaving the feathers soft and limber. After being sorted into bundles of twelve, held together by clothes pins, they go to the duster-makers. The machines for winding dusters are similar to those used in broom-winding, and the operations are almost identical. The wooden handle is cut into grooves with shoulders, by which the feathers are firmly bound by the tightly drawn wire. The "skirt" or fluffy part of the duster is made from the downy feathers nearest the body of the bird, and the cup or base covering of leather or paper completes this very necessary article of trade.

Of the industries which blind men may learn in the institution and follow outside in their home towns, cobbling and rug-making offer the greatest returns. Almost any corner of the main street in the village will support a little cobbler's shop, and all the work is brought in and called for. All the shoe repairing in the institution and some from outside is done by the blind cobblers, and they have even undertaken the making of shoes for themselves. The accuracy, style, and finish of their work is remarkable. Rug-making from old carpets offers many advantages to blind men. The work is simple, the looms suitable for their work are inexpensive; and, where the worker is well known plenty of weaving can be found. All those from the institution, who have set up looms of their own, are doing well.

The profitable occupations suited to the physical limitations of blind women are not so readily found. Chair-caning, raffia-work in basket-making and other forms, tapestry weaving, stenography and typewriting, hair-dressing and massage, and domestic science, when thoroughly mastered, offer a fair livelihood. Of these tapestry weaving and stenography are, perhaps, the most promising. A large amount of chair recaning is done in the institution, mostly by the blind past middle age, and is to the women what broom-making is to the men, in furnishing steady and at the same time profitable employment. The guide who shows visitors through the institution is a blind girl, and she is so familiar with every turn, every doorway and stair, and talks so intelligently of the work, that it is hard to believe she lives and moves in a world of total darkness.

The tapestry looms, which are constructed to meet the special requirements of the blind, are an interesting feature of the institution, and may be said to solve the industrial problem for blind women. They are operated entirely by hand; but by diligent application the difficulties are overcome, and towels, table scarfs, sofa pillows, laundry bags, and similar articles are woven entirely from the raw material. Complicated designs in flowers, trees, animals, emblems, and geometrical lines and figures, are reproduced in the linen with absolute faithfulness and exquisite finish. The artistic touch, too, reveals a conception so subtle, and deftness so precise, as to seem incredible in persons without sight. The sense of feeling is, in this absorbing work, most highly specialized.

The paper pattern, by which the design to be woven in the linen is communicated to the mind of the operator, is a marvel of simplicity, and is easily made by a sighted person. A small sheet of ordinary cross-section paper, such as is used by surveyors, and which is ruled in little squares one-eighth of an inch in size, is embossed by pin pricks, so that each one represents a thread of the warp

which enters into the figure. Likewise, other pricks on the vertical lines reveal the outline and composition of the figure, and by them the woof is laid. The blind operator, by an exceedingly light but rapid touch reads a portion of the pattern, and lays down as many threads as called for by the pin pricks. The particular shuttle is then slipped through, and the operation is repeated until the figures and the fabric itself are finished. A table scarf, twenty by twenty-eight inches, with a pine tree design done in green, was made in fourteen and a half hours, and the cost including the linen and silk, was one dollar and seventy-four cents. The actual value was considerably more; the difference represented the returns for the operator's time and a reasonable margin of profit.

Instruction in the use of the ordinary typewriter, and in reading the various point systems for the blind, are important courses taught in the institution. It is given under the direction of A. M. Shotwell, the able librarian; though blind, he is an authority on all matters pertaining to those so afflicted. Many of the inmates, who became blind in later life, and have had no chance to learn to read or to use the typewriter, find these privileges of the greatest value. To be able to read once more, even though it be a slow and laborious task, and to communicate with others by putting his thoughts on paper, after years of not having written a single letter, is a source of boundless pleasure to every blind person.

Shorthand for the blind is an assured fact, and is now regarded as a practical field for them. This seemingly impossible accomplishment is made entirely feasible by the use of a wonderful machine, so simple in its mechanism, yet arbitrary in its action, as to surprise those who have witnessed its operation under the deft manipulation of the sightless, skilled in the art. It weighs only nine pounds, and has only six keys with which to form all the combinations used in the system; yet the operator can take the most rapid dictation and afterwards read

the notes correctly. The process is simply to press on the keys with a quick, elastic touch, by which the raised shorthand type cipher is printed on a slip of white paper, which unwinds from a large spool and travels across a tray on the top of the machine. After the dictation has been taken, the paper is rolled back again, and is then ready to be read with the fingers and transcribed on the typewriter. It is possible after much practice to attain a high rate of speed. There are possibilities in this field for the sightless as yet not realized by them.

It has been found by experience that many pursuits that blind people can follow cannot be worked with enough rapidity to make them practical as life work. To illustrate: Blind girls are perfectly capable of doing the best kind of work with ordinary knitting machines, such as are used in all knitting factories, but they work so slowly that they cannot make wages enough to keep themselves. And when it is remembered that among those who can see, nearly every artisan of any skill or proficiency learns a trade before he is twenty-one years of age, the difficulties attendant on taking people who have become blind late in life and teaching them to become skilled workers and at the same time rapid ones, can be slightly appreciated. Among the men who have been admitted, some were formerly farm-hands, machinists, painters, sawyers, railroad firemen, expert bookkeepers, graduate druggists, some from the army and navy, and many who, from having been blind from childhood, have no trades at all. The task of helping these people to adapt themselves to new conditions, to form new life habits; the task of encouraging and cheering the most despondent ones, and of making those with families believe that they can, by hard work, again help to take care of those dependent upon them, is no easy one.

One of the most important features of the institution's work is the Free Lending Library which the established act requires to be conducted. By the provisions of the

Rucker Bill, which was passed by Congress and became a law on April 27, 1904, reading matter for the blind may be sent free of postage anywhere in the United States, when sent from or returned to a free lending library. Scattered throughout Michigan and every other State are many blind people to whom books of the various Braille point systems are sent when called for, and, after being read or studied are returned to the library. Thus to many not in the institution, hours of recreation and profitable study are given, as the list of books includes works of history, poetry, fiction, science, music, and current literature, including a magazine regularly published in the Braille.

The library now contains several thousand volumes divided among the Roman line-letter, the European Braille, the New York point, and the American Braille, the last named being the official recognized embossed type of the State. It is the system preferably taught in the institution, aside from the official choice, for several reasons. In the first place it provides for capitalization and punctuation, and symbols for contractions, features considered valuable to advanced students and teachers of the blind. Being a three-point system, it requires more space than the New York point, which is two-point, but the advantages named more than balance the defects of the latter. All books for the blind are bulky and heavy volumes, and to pack them for mailing, strong cloth cases are used of the telescope kind, the two parts being strapped securely together. To render the return of the package easy for the borrower, the name and address of the institution is printed in large, bold letters on the cover of the case, so that miscarriage is impossible. When the case goes to the borrower, a tag with the name and address printed on an ordinary typewriter, is attached to the case covering the name and address of the institution, and tied down with stout twine. All the borrower has to do is to detach the tag and secure it through holes

in the upper left-hand corner of the case and tie it down. The simple and easy scheme was devised by Mr. Shotwell, the blind librarian, who by education and temperament is well qualified for the rather exacting work of the library. In all matters looking to the welfare of blind folk, he is their proved friend and adviser.

As some kind of intense occupation is life for the sightless, so cards and music are their most absorbing pleasures. In their world of darkness outside of the world, they derive a keen joy in the triumph of their finest sensibilities over the crude. It is a battling of their pure intelligences, a conflict which the sighted, with their gross sight sensations, know not. At a card table the stone-blind skin their cards with fleeting smiles of satisfaction, or frowns of displeasure. They have no need to train their faces, but use their voices for deception, or are silent. They use the ordinary cards with embossed points on the upper left-hand corner of the ends, and they are read in being taken from the table with a negligence and deftness that are surprising.

"They have beaten full-sighted players every time they have met," remarked the librarian, "and this has led some to suspect that the dealer's fingers read the cards he dealt, as they deal from the centre of the pack." "That is not so, however," he continued, "but rather the manifestation of a most wonderful and subtle mind-reading. The very darkness, aided by wilful silence, makes hearing and touch — touch of vibrations — painfully acute; and the dawning sixth sense of man, which you feel faintly sometimes, and act on subconsciously more often, has special opportunity to concentrate itself in subjects sharply responsive to it."

Two or three of the most deft devotees of the game have actually played with cards not embossed. "How is it done?" By the feel of the forms of ink-prints on the faces, which their super-sensitive fingers reveal to them. The picture cards are readily distinguished from

the others in this way, but determining the suits is much more delicate. The calling of suit and value of a picture card is the culmination of the blind man's wonder-trick.

With all the good work being done, the institution in Saginaw is not a copy of any other trades-school; and its work and methods are very different in important particulars from those of any other working home or trade-training school for blind adults.

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